DEVELOPMENT OF A TINY HOUSE RAINWATER CATCHMENT SYSTEM (RCS)

Bachelor Graduation Project, Creative Technology, Marnix Riepen
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March 2022

Abstract

Living fully off grid for Tiny House owners means that they are not connected to any network, such as the electricity network or water network. Electricity can be collected using solar panels. However, few solutions have been realized or are widely used for the collection of clean water. The solutions that do exist are never big enough to collect enough rainwater for a Tiny House household of 2. The estimated water usage of a Tiny House household of 2 persons is 48 000 liters of water per year. Taking the average rainfall of the Netherlands into account, a rainwater catchment area (ground area) of around 60 squared meters is needed to collect enough water for two adults. Existing Rainwater Harvest systems use the roof of the Tiny House as the Rainwater Catchment system (RCS). However, the most tiny houses have a smaller roof area than what is to collect water. Furthermore, the roof may contaminate the water with bird droppings, leaves and other pollutants.

This bachelor thesis describes the process of developing a RCS for a Tiny house household of 2 persons that reduces the water contamination of existing RCS's. First, a literature research on water usage, portability, Dutch weather and existing products was conducted. After the research, different requirements were stated and concepts were ideated. One concept was chosen with the help of the stakeholders. New more specified functional and non-functional requirements were stated for this concept. The final concept was used to build a scaled down prototype of the new RCS. The prototype includes a rollable Collector sail that only opens when it rains, to prevent the chance that pollutants will be collected by the Collector. Evaluation was done with multiple Tiny House owners and showed that such system could be used and would be functional, especially if water becomes more expensive. However, the dimensions are too large for next to the Tiny House, so it would be more interesting that the new RCS would be used next to an existing roof RCS.

Acknowledgement

There are multiple people I would like to thank for their help and support. Firstly, I would like to thank my supervisors Richard Bults and Katarzyna Zalewska for their supervision, guidance and support throughout my Graduation Project. In addition, I would like to thank Alfred de Vries for all the help to get the materials I needed for building my prototype and helping out with the 3D prints. Furthermore, I would thank my friends and family for their help and input during the project. Finally, I would like to thank all my participants of the questionnaire and interviews.

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Chapter 1 – Introduction

Off-grid living is one of the most freeing things to do for a lot of people. This is done in multiple ways for example in Tiny Houses, vehicles and boats [1], [2]. Living totally off grid means that the place where you live is not connected to the public supply of electricity, gas, water, etc. [3]. There are already multiple solutions for generating electricity off-grid [4]. According to internet communities, many off-grid dwellers find it difficult to get water and especially potable water [5] [6]. At the moment, people have to fill their water reservoirs at public supply points such as campgrounds and road stops. To be off-grid for longer, people make their water storage bigger or stay near a freshwater source. For a permanent settlement the size of the water storage unit can be much larger because it does not need to be moved around. However, for portable Tiny Houses and other off-grid habitats space and weight is limited. Thus, getting larger storage units creates a portability problem.

Another way Tiny House owners get their water is by using a Rainwater Harvest System (RHS). RHS can be defined as the direct collection and use of rainwater. [7] RHS collects water in two different ways. One way is getting water by using the roof as a catchment surface. The other way is using a surface next to the house. This water then can be potentially used in the Tiny House for drinking water or grey water. In both cases there is a problem of getting the rainwater as clean as possible. Bird droppings, tree leaves or pieces of branches that build up on the surface of the water catchment system together with feathers, wools, insects, etc. pollute the harvested rainwater.

These pollutants must all be filtered out, but water filters that perform this function are expensive and/or require high maintenance. Another way of getting a better water intake from a dirty catchment area is with a so called 'first flush'. The first flush means the first part of the water that is collected, which contains the highest concentration of contaminants, is stored somewhere else then in the water storage. In this first flush, 0.1 to 3.8 mm of the rainfall is lost. [8] This is a big waste of rainwater. One potential way to avoid losing water to contamination is to outfit the RHS with a dynamic Rainwater Catchment System. Such a system could ensure that the water catchment surface remains clean. Thus, the water intake of a RHS will be cleaner and it will be easier to make the water usable or even potable. Such a system should be low in maintenance, weatherproof, portable and big enough to get enough water for a minimum of 1-2 persons Tiny House household.

The challenge is to replace the roof of a Tiny House as a catchment surface of a RHS with an alternative solution that reduces water contamination. In order to obtain sufficient water for a 1–2 persons household, the surface of the alternative solution must adequate. Reduction of water contamination should be accomplished by a low maintenance cleaning solution. In addition, the solution should be portable. To fully fulfill the whole Tiny House community, including the ones that lives on wheels, the system needs to be easily transportable with the household. Finally, the alternative solution must be strong enough to be used in all-weather circumstances. Preliminary requirements lead to the following research questions:

What is needed to develop a Rainwater Catchment System for a Tiny House that reduces water contamination?

Sub questions are:

1. What is an adequate catchment surface area of this subsystem for a 1 or 2-person household in the Netherlands?

2. What methods exist to make this subsystem low maintenance?

3. What methods exist to make this subsystem portable?

4. What methods exist to make this subsystem weatherproof in the Netherlands?

Chapter 2 – Background Research/Design space

In this chapter, a design space will be formed. This space will include research about the sub questions listed in the introduction, an analysis of state of the art of water catchment systems and expert knowledge.

This design space is ordered logically by the topics of the sub questions. First the surface of the catchment area needs to be defined, because it forms a clear boundary condition on what type of solutions are realistic. Secondly, more should be known about how to make the product as low maintenance as possible. It should be low maintenance because the user should not have to deal with their water source, to make it easy for the product to replace the normal grid solution. Thirdly, it is important to know how a product can be portable. This would make the market of the product bigger.

A wider range of users could use this product if it is more portable, for instance people living in a campervan or boat. Also, some Tiny Houses are on wheels and will be moved a lot around the country. The product should provide for those persons as well. Lastly, the product should be weatherproof, because this product will be used in the rain outside of the house. It should be able to withstand all elements that can be found outside, for instance rain, snow, temperature and winds. In addition to this there is a state of the art. The purpose of the state of the art is to see what already is done and what concepts can be reused in the product.

2.1 Surface Catchment area

When designing a new low maintenance RHS catchment area, some principal things should be known. This is important because the catchment area directly influences the total amount of water that is collected. The total water collected should at least be the same as the water usage of the user. So the user do not need another source of water. Firstly, the total surface area should be calculated. This can be derived from this formula:

$$RWH\ potential = P * A * RC$$

Formula 1 RWH potential

The Rainwater harvesting (RWH) potential (in l/year) of a roof can be estimated based on the local precipitation (*P*, in mm/year), the catchment area (*A*, in m2) and the runoff coefficient (RC, nondimensional). [9] The RC is a dimensionless value that estimates the portion of rainfall that becomes runoff, taking into account losses due to spillage, leakage, catchment surface wetting and evaporation. [10] The RC value depends mostly on the slope and the roughness of the roof. [9]

Given this formula a new formula can be formed where RWS potential should be changed to water usage of a Tiny House of 1-2 persons. The Area should be calculated for Dutch climate conditions.

$$A = \frac{water\ usage}{P * RC}$$

Formula 2 Area rainwater harvest

where A is the catchment area (m2), water usage is the amount of water used by a Tiny House household of 1-2 persons (l), P is precipitation average of the Dutch weather (mm/year) and RC is the runoff coefficient (nondimensional).

With the help of formula (2) the unknown variables are the following topics for this chapter.

2.1.1 Tiny Household water consumption

First the water consumption of a 1-2 person Tiny Household should be known. In formula 2, this is the water usage. Searching on Tiny House owners blogs, they use with 2 persons 132.5 liters of water per day [11]. Other research [12] shows that adding all different types of water usage together a person uses 64 liters per day. [12] As can be seen in Table 3, the total use is 64 liters a day per person. This research assumes that the persons will have a compost toilet and that they do their laundry not at home.

Table 3 Total water consumption of 1 person in a Tiny House

Water Activity	Liters/Day/person
Drinking	3.8
1.5 GPM shower head	46.6
general hygiene	4.5
hand-washing dishers/full sink	9.1
	64

Source: adapted from [12]

2.1.2 Precipitation

This research is focused on a Tiny House household in the Netherlands. Therefore, knowing the average precipitation in the Netherlands is important to fill in the formula 2. In calendar year 2020, the total precipitation per year in the Netherlands was around 876 mm per squared meter. [13] This means for every square meter 876 liters of rainwater could potentially be collected per year. However, this trend is going up so in the next coming years this could even be more. [13] See Figure 2.

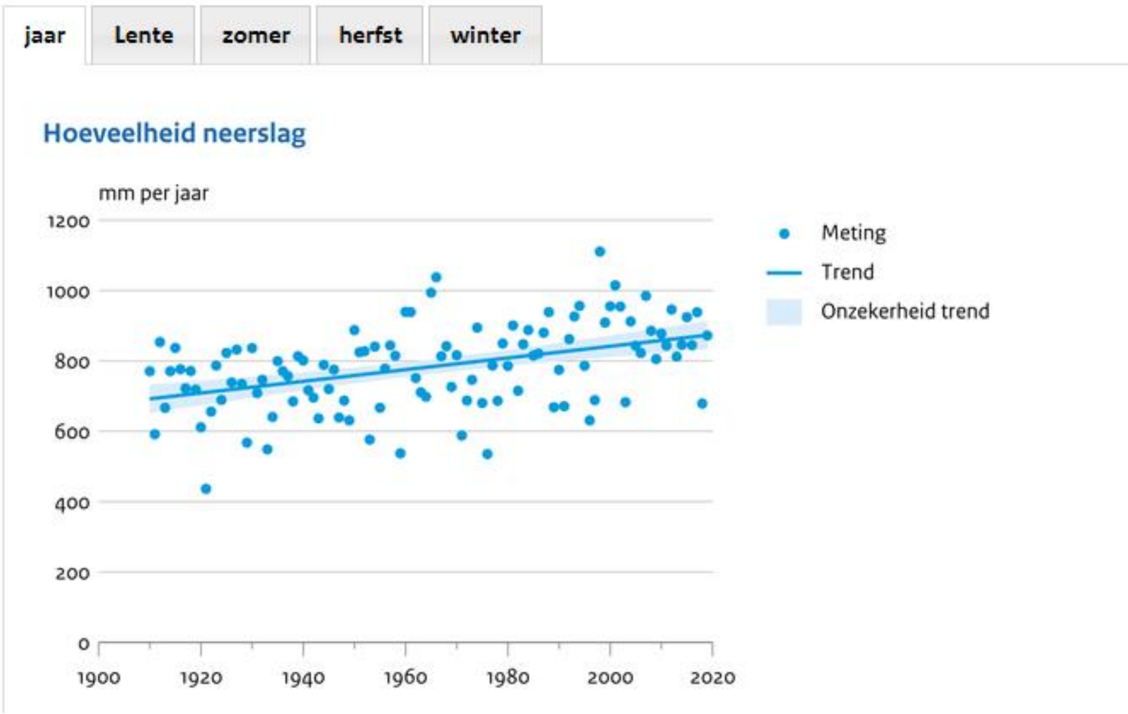


Figure 1 Amount precipitation

Source: adapted from [13]

2.1.3 Runoff Coefficient

The Runoff Coefficient (RC) depends on several factors; i.e., the roughness of the surface, the slope of the catchment area and material usage of catchment area. However, the first 2 parameters are the most influential [9] . When using a material with a low roughness coefficient at a specific angle this coefficient can be up to 0.90. Other materials and slope give different RC values. For example, the RC of a flat roof made of Bituminous is 0.7. The RC of a sloped roof of aluminum is 0.7

2.1.4 Total calculated catchment surface area

Filling in formula (2) with all information found above, the minimal catchment area can be calculated.

$$A_{min} = \frac{128 * 365}{876 * 0.9}$$

The catchment surface area should be a minimum of 59.3 square meters to fulfill the total water need of a Tiny House household of 2 persons per person. Keep in mind that the harvested rainwater must be stored to have water available during dry weather conditions. However this is most optimistic scenario. Lowering the RC to 0.7 the total area will be 76.2 square meter.

2.2 Low-maintenance

In this design frame, low-maintenance means that the user have to interact as minimal the product. It should be fully automatic and should not be cleaned/handled in a way to be functional. However the user still need to be able to put the product on/off. This low-maintenance aspect is important to make the product a good replacement for the “normal” situation (being connected to the water grid). Normally when Tiny House owners are connected to the grid they do not have to do any maintenance for getting water. To switch over to an off-grid solution could be a step too far because a way of getting water off-grid is by using the roof, with a filter and a first flush. The first flush works as follows: The first water that is caught will collect contamination from the surface area. This water goes to the vertical pipe where a ball floats on the water and when there is so much water in the pipe the ball blocks the opening and now the water goes to the water container/tank. This water in the vertical pipe should be discharged by a person. So somebody needs to go to this pipe every time after it rained to discharge the water of the first flush. An example can be seen in Figure 3.

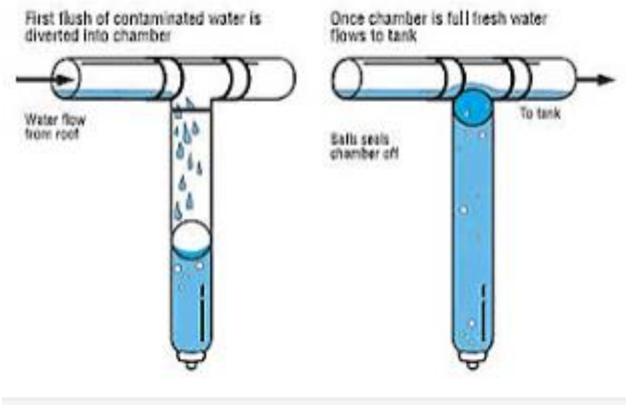


Figure 2 First Flush drawing

Source: adapted from [14]

Here is another simple schematic of a first flush system.

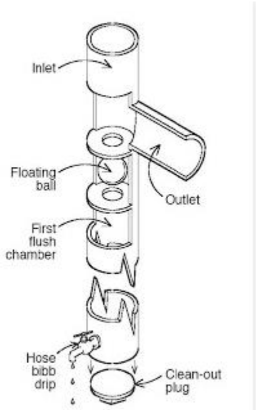


Figure 3 schematic first flush

Source: adapted from [14]

Another option to get rid of the contaminants is by cleaning the roof multiple times a year. This again is a very high maintenance job. The off-grid solutions should be out of the design frame to make the product low maintenance.

2.3 Weatherproof

Thee product should be weatherproof. Weatherproof means resistant to bad weather conditions, for instance rain, wind and snow. To make a product weatherproof it should be able to resist hard wind, it should be waterproof, and snow should not break the product. Also, temperature fluctuations should not influence the use of the product.

For example, the RWS will be portable so when the weather conditions are too severe strong it should be put in a state that it is protected from these conditions.

2.3.1 Wind

In the Netherlands winds can be strong so it would be good if the RWS could be used during normal winds and withstand up to a code yellow. Code yellow is in the Netherlands winds stronger then 75 kilometers per hour. [15] This will make the design frame smaller. By adding requirements to the sturdiness of the product.

2.3.2 Rain

The product should be waterproof and be made from nonrusting materials. This is because it will be collecting rainwater and so be outside when there is water. For example, untreated metal can rust. In addition, exposed metal surfaces can contaminate the water with heavy metals and should be treated in various ways and disinfected. [16]

2.3.3 Temperature

The next important thing is that it can handle the temperature differences. In the Netherlands the maximum and minimum temperature in a year are given in Figure 5.

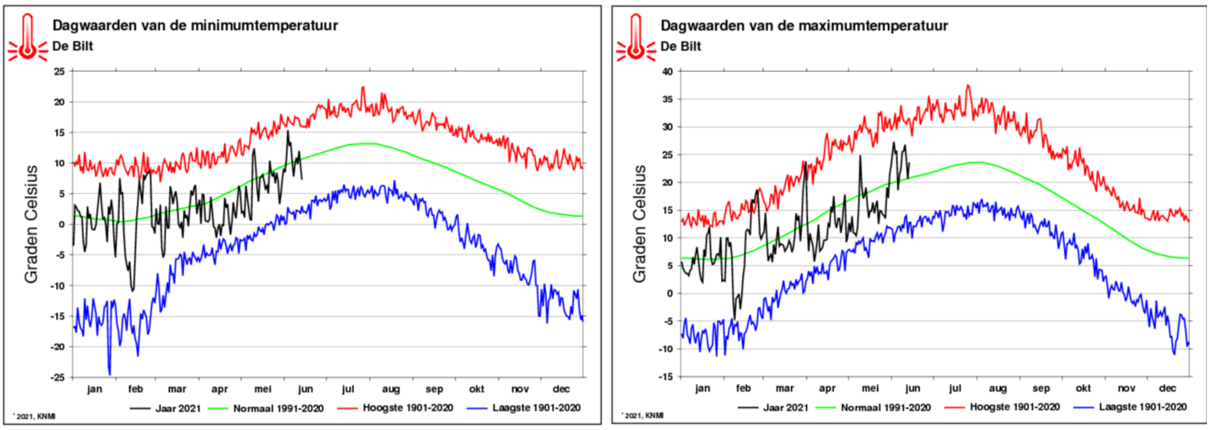


Figure 4 Day level of minimum and maximum temperature of the KNMI weather station "De Bilt".

Source: adapted from [17]

The product should withstand less than 35 degrees and more than -25 degrees and the materials used can flex enough with these temperatures. When the product is able to withstand these temperatures it can be stored outside. However, materials that are exposed directly to the sun can get even hotter. Interiors of conduits located on rooftops in full sunlight become considerably hotter than those located in shaded areas. [18]

2.3.4 Snow

In the Netherlands snow is a yearly occurrence. On average there are 10 days of snow [19]. Snows density is around 200 kg per cubic meter; 10 cm of snow is 20 kg per square meter. When the catchment area should be 60 square meters, the total weight of snow on the catchment area 20 * 60 = 1200 kg

2.4 Portability

The whole Tiny House community does not live all at a fixed spot. Some houses are made on a trailer and can be moved to different places. To suit these people as well, the product should be portable. Mital et al. [20] says that a product is portable if at least the following 3 criteria are met:

1. It should be possible to move it from one place to another without the assistance of either a mechanical aid or other individuals.

2. The process of carrying should not cause excessive fatigue, exhaustion or over-exertion

3. The product should be sturdy and be able to absorb a few knocks and bumps without sustaining any damage.

However, there are just a view design methods and tools currently available to realize a portable product. H. Dongwook and P.Woojin [21] have made some ready-to-use design heuristics. For the ideation phase of this research their brainstorming-based design method that will utilize the design heuristics could be used. To make these heuristics clear Table 3 is made.

Table 4 Portability Table

Meta-heuristic	Heuristic	Description
Shrink in size	Transform	Transform an object for easy carriage (e.g. fold, roll, transform, etc.)
	Segment	Divide an object into independent parts or make an object sectional
	Use nesting	Place one object inside another
Use advanced materials	Utilize elasticity	Use elastic materials
	Select waterproof materials	Use new materials which are waterproof
	Select flexible materials	Replace customary constructions with flexible material
	Select light materials	Use materials light enough to hold with hand(s)
Add protection	Use rigid outer protection	Provide rigid outer protection to improve portability
	Provide within a container	Store the content inside a container protecting from external stresses
Extract	Utilize what is already portable	Extract parts from an object and integrate them to what is already portable
	Extract essential parts	Extract only essential parts/properties from an object to maintain original functionality
Universalize	Standardize	Standardize products, components and interfaces
	Provide an intermediary or a connector	Provide an intermediary/connector
	Use multiple connectors	Provide ways for interfacing with multiple devices/elements
Provide power supply	Include battery	Store energy in batteries and use them as energy source
	Provide energy through harvesting	Provide energy through harvesting as power source
	Convert energy	Convert energy to generate power
Simplify	Organize/unclutter	Group objects performing related functions
	Combine into one	Combine multiple entities with different functions into one entity
	Reduce unnecessary parts	Reduce unnecessary parts while maintaining original functionality
	Add multiple functions	Add multiple functions to a single object
Provide ease of use	Reduce stress	Reduce stresses on the human body
	Provide grips/handles	Attach grips or handles
	Attach wheels	Attach wheels to an object
	Provide adjustability	Provide adjustability to enhance flexibility
	Use fixture	Fixate not to fall down and get damaged
	Attach to body parts	Design a product to be a wearable

2.5 State of the art

The state of the art of the rainwater harvest systems will provide information on existing products and a design technique, origami.

2.5.1 Existing products

The most usual way to collect rainwater is via the roof. Multiple big companies are installing such systems on houses. Here is a small list of companies that uses a roof RHS.

Postma Kunststof Tanks [22] sells the water storage containers and installs the total RHS. However, they use the roof as the catchment area. A downspout brings the water towards the storage tanks. The filter system will not make the rainwater potable. Many other companies do the same such as Rainwater Harvesting [23] , RainHarvest Systems [24] or Mijn Waterfabriek [25]. Only the filters and pumps are different. The next Figures give an example of what kind of systems these companies sell. In Figure 6 a storage unit, a filter and a pump can be seen. The next Figure shows a schematic of how these units are installed and how it works. The pros of this system are that they can provide enough water for a household of 2 persons. However, the costs are high and the products are underground so not portable.

Figure 5 Pump, filter and storage for RHS

Source: adapted from [22]

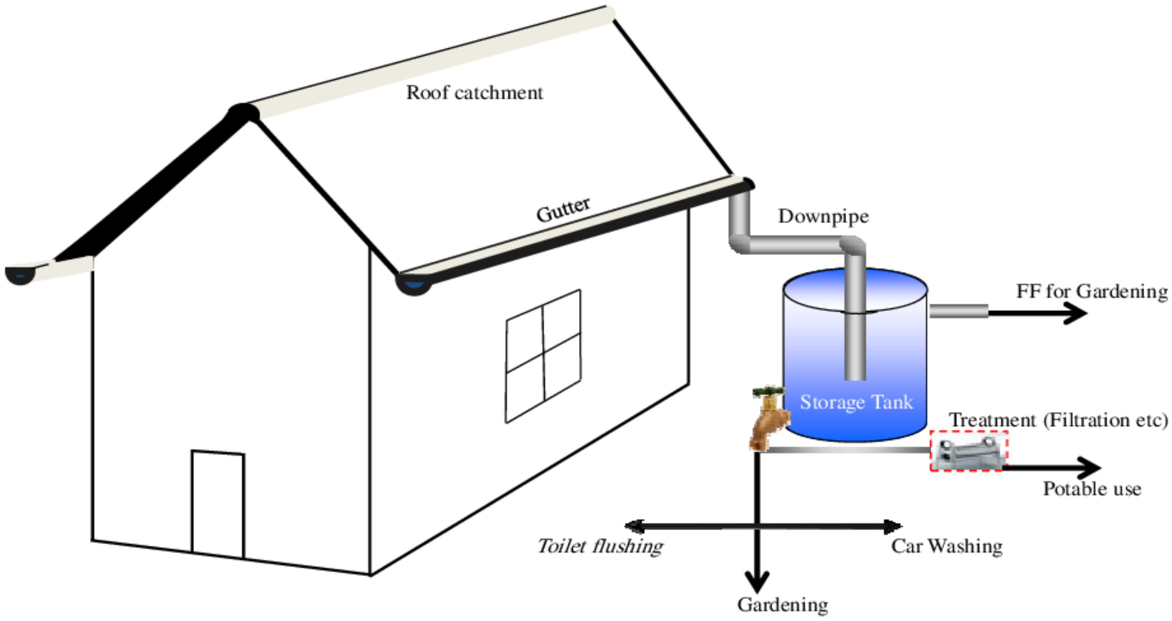


Figure 6 Clear overview of a Rooftop RHS

Source: adapted from [26]

However, there are also different catchment areas instead of a roof. For example, a circular catchment area from plastic is made by RainSaucers [27]. This catchment surface is mounted on top of a water barrel as can be seen in Figure 8. Due to the ropes on the side, the product can resist up to 80 kilometer per hour winds. However, these barrels will not provide enough water for a household of 2 persons.

Figure 7 RainSaucers RHS

Source: adapted from [27]

This idea is made in different ways, some more arty then the other. Here is an example:

Figure 8 Umbrella RHS

Source: adapted from [28]

An umbrella kind of water catchment area can be used to be opened when there is rain and closed when there is no rain, to keep out most of the contaminants so the area stays clean. Also umbrellas are water resistant and can withstand the temperatures of the Netherlands. The canopy (the part of an umbrella that blocks the rain) is made from fabrics or plastics that are water repellent. Silk, acetate, rayon and nylon make rain- and sun- resistant fabrics for umbrellas [29]. However such system is not made yet in the right size, to provide enough water and this umbrella should be opened and closed by a person. There are some prototypes of umbrellas that have a rainsensor and a motor to open automatically when it rains. This can be seen in Figure 10.

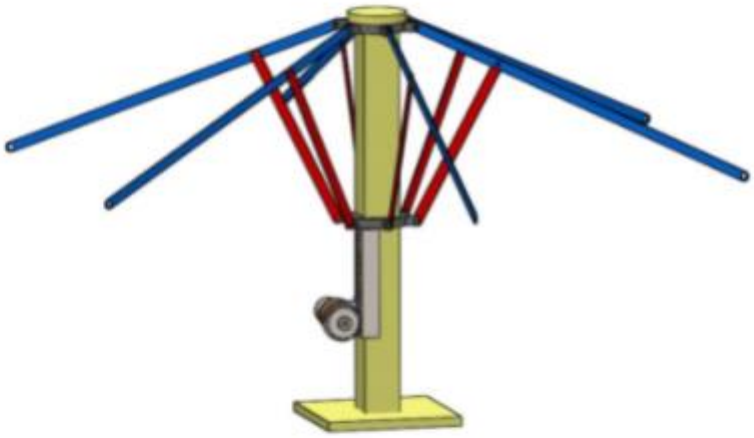


Figure 9 Automatic Rain Water Sensing Umbrella

Source: adapted from [30]

Pros of such system are that it automatically opens and closes. This will result in low maintenance. Less contaminants can be caught. Cons it is not yet a rainwater harvest system. And the folding technique of the product leads to a very high pole, if 61 meters catchment area is realized.

Hilico [30] is a bit different. They really focus on the portable design part. It says that they are the first portable rainwater collector. Its design maximize efficiency while withstanding wind. It is simple to set up (2 minutes). In the Figures below Hilico product can be seen. Cons of this product is the total catchment area and high maintenance. This product will not catch enough water for a household of 2 persons and should be deployed by a person. It would be more interesting if this catchment area deploys by it self.

Figure 10 Hilico product deployed and closed

Source: adapted from [31]

Another company is EcoCabins [31]; this company makes Tiny Houses. They use the roof like the companies in the beginning of the state of the art. However, in the future they are going to work with two other companies to develop fully off-grid Tiny House solutions. Metropolder [32] is one of the companies. They make Polder Roofs [33]that serves as a smart, controlled water storage. On this storage plants can grow. However, the water that will be catched by the Polder Roof can only be used for cooling down the roof itself and the solar cells that could be on the roof. The second company Ecocabins works with is Hydraloop [34]. Hydraloop designs and produces decentralized water recycling products. In short, they make a filter system to reuse greywater. EcoCabins shows that there is still not a really good solution to get fully off-grid due to not having a good way to collect water. The products of these companies can be seen in the Figure 12.

Figure 11 Eco Cabin - Hydraloop - Polder Roof

Source: adapted from [32] [35] [33]

These are some of the direct companies that have the same idea. However, to be as innovative as possible, it is handy to look at companies that needs to keep things clean for instance.

Pool covers are a way to keep the pool water clean from the same contaminants that roofs have. Here some examples of pool covers:

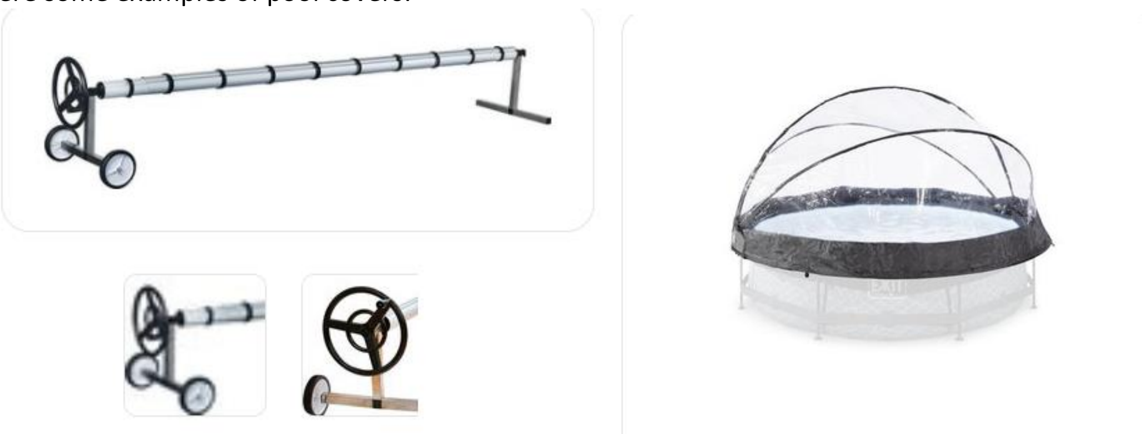


Figure 12 Pool covers

Source: adapted from [35]

Pool covers cover the pool when it is not being used. This could be also done with the RHS. These covers can for instance cover a roof when not used. However, it can be used as a way to catch water next to the house!

2.5.2 Origami

With the knowledge of the literature a catchment area surface has been calculated. The catchment area should be around 61 meters for a 2 persons household. Also, the product should be portable to fulfill the full community. In addition, the product should be as low maintenance possible. Being able to fold the surface area away when there is no rain can lead to less contaminants and therefore potentially lower in maintenance. Origami could be a technique to use for the envisioned product. Origami can lead to extreme portability, storability and deployability of products. [36]. To utilize this design method 4 steps are needed. First define the problem, then search for the origami solution, modify fold pattern and at last integration [37]. A great example of an origami-based design product is the Starshade that is being made by NASA [38].This is one of the origami solutions that will be investigated. The other one is the Miura Ori technique. Both folds are a way to go from a small form factor to a large area; in this research a large rainwater catchment area.

Flasher technique

The Starshade is a flasher type of origami, the flasher origami can be seen in Figure 14. It folds from a flat form to a cylinder form. The Starshade is used to prevent all starlight from entering a telescope. It allows many simplifications of the telescope and camera optics. [39] The flasher origami technique is used in the hub of this Starshade. The diameter from this hub converts from 2.2 meters to 10.5. [40] The Starshape design can be seen in Figure 15.

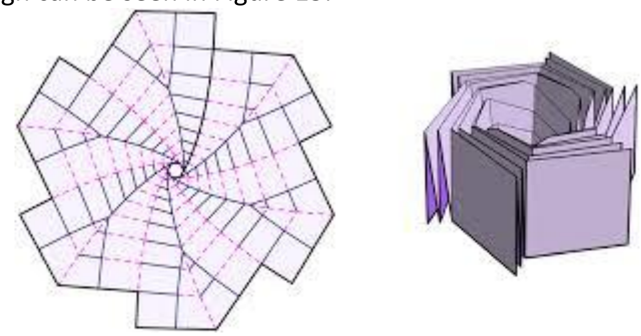


Figure 13 flasher type of origami

Source: adapted from [41]

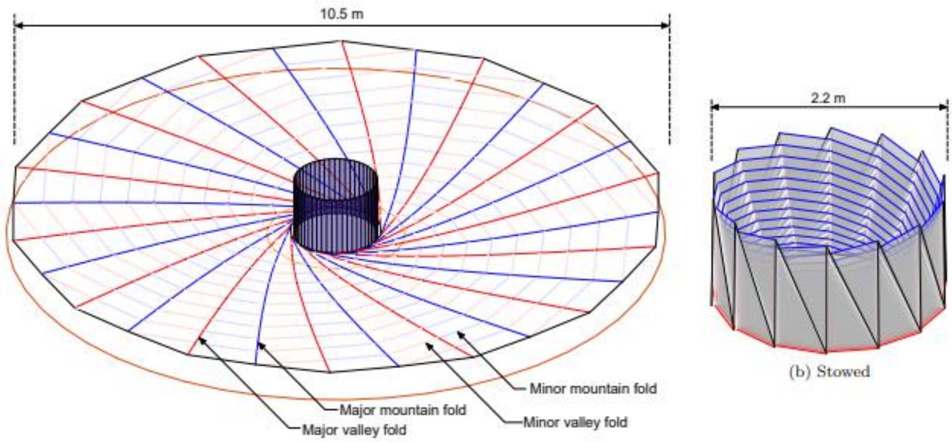


Figure 14 dimensions of Starshade hub

Source: adapted from [40]

The flasher technique will make a flat round sheet into a cylindrical form. This can then be stored when not in use. Another technique is the Miura Ori.

Miura Ori

Miura Ori will go from a horizontal flat sheet to a vertical flat sheet. This technique can be seen in Figure 16. The Miura-Ori pattern got some really intriguing mechanical features such as the one Degree Of Freedom mobility, auxetic in-plane behavior and energy absorption capability. [42] These properties could be used to make the catchment surface weatherproof because of the absorption capability for wind for example. Also because of the one degree of freedom this plane could be opened on one axis.

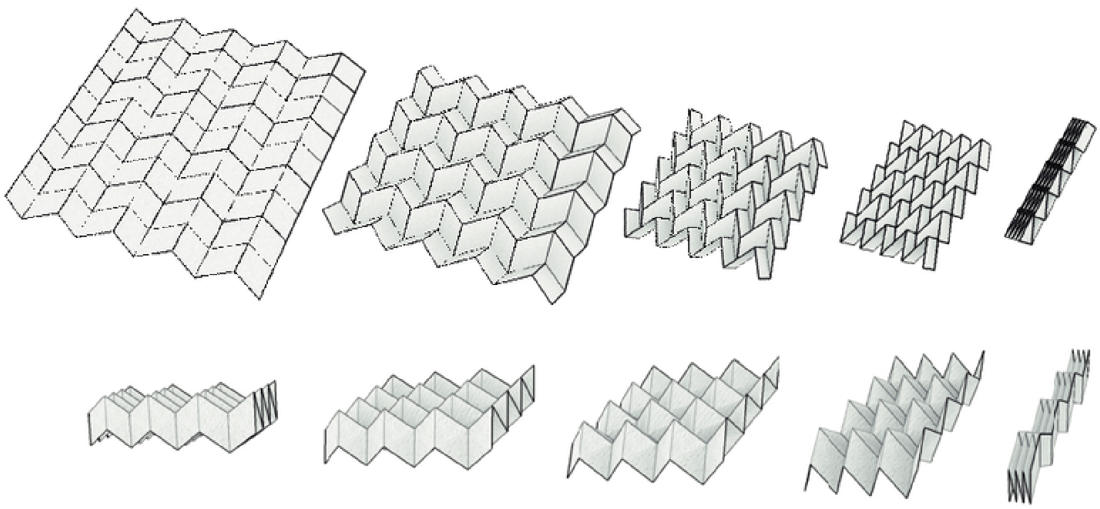


Figure 15 Miura Ori fold schematic

Source: adapted from [42]

Cons of origami are that is pretty hard to make rigid but also very flexible materials foldable . Also with the Miura Ori there are a lot of seems where water could stay stuck.

2.6 Conclusion

To conclude, in this chapter a design space is explored. If the products surface is 61 squared meters or larger it will fulfill the needs of a Tiny House household of 2 persons. The product is low maintenance if: no first flush is needed, no extra cleaning is needed or the product have to be interacted by person to be functional. The weather in the Netherlands is rainy, with 873 mm of rainfall in 2020. The normal winds (without a specific color code) is maximal 75 kilometer per hour. Snow falls 10 times a year on average and is pretty heavy. So if possible, snow should be avoided. To make the product portable, H. Dongwook and P.Woojin design heuristics can be used. Other RHS catchment areas are roofs, umbrellas or tarp kind of structures (Hilico). However, a creative way of catching water is by using origami techniques. In this way multiple topics of the design space can be tackled. This could be researched more in the ideation phase.

Chapter 3 – Methods and Techniques

Chapter 3 contains the methods and techniques that are used for the Graduation Project. This chapter is needed to structure the following phases. The following phases are ideation, specification, realization and evaluation. This structure is based on the Creative Technology Design Process. In addition to these global phases, specific techniques are used. In the ideation phase, a stakeholder analysis, brainstorm sessions, collage making and concept making, are done. Furthermore requirements are made and prioritized. Afterwards in the specification phase, better design making, user scenarios and interaction analysis are done. The function decomposition is visualized with the help of a level approach method. In the realization phase a prototype will be built and tested. In the evaluation phase a questionnaire will be made and sent to the stakeholder, the Tiny House community.

3.1 Creative Technology Design Process

In Figure 17 the Creative Technology Design Process is shown. This process will be used for this graduation project. The process uses 4 clear phases, these can be seen in the Figure below. The first phase is the ideation phase. This phase is about identifying and defining the problem. When the problem is defined different various ideas will be explored and requirements will be stated. In this report this phase is executed with multiple different ways to generate ideas such as brainstorming, sketching, collage making and conceptualizing. The second phase is the specification. During this phase, the chosen concept is worked out in greater detail. In this thesis this will be done with the help of an interaction analysis and user scenarios. In addition, more specific requirements are made for the design, in the form of functional and non functional requirements. The third phase is the realization, here all different components that are thought of in the previous phases will come together. In this phase a prototype will be built of the end product. The last phase is the evaluation. This phase is about testing and reflecting on the prototype. In this project this is done with the help of the Tiny House community with the help of a questionnaire.

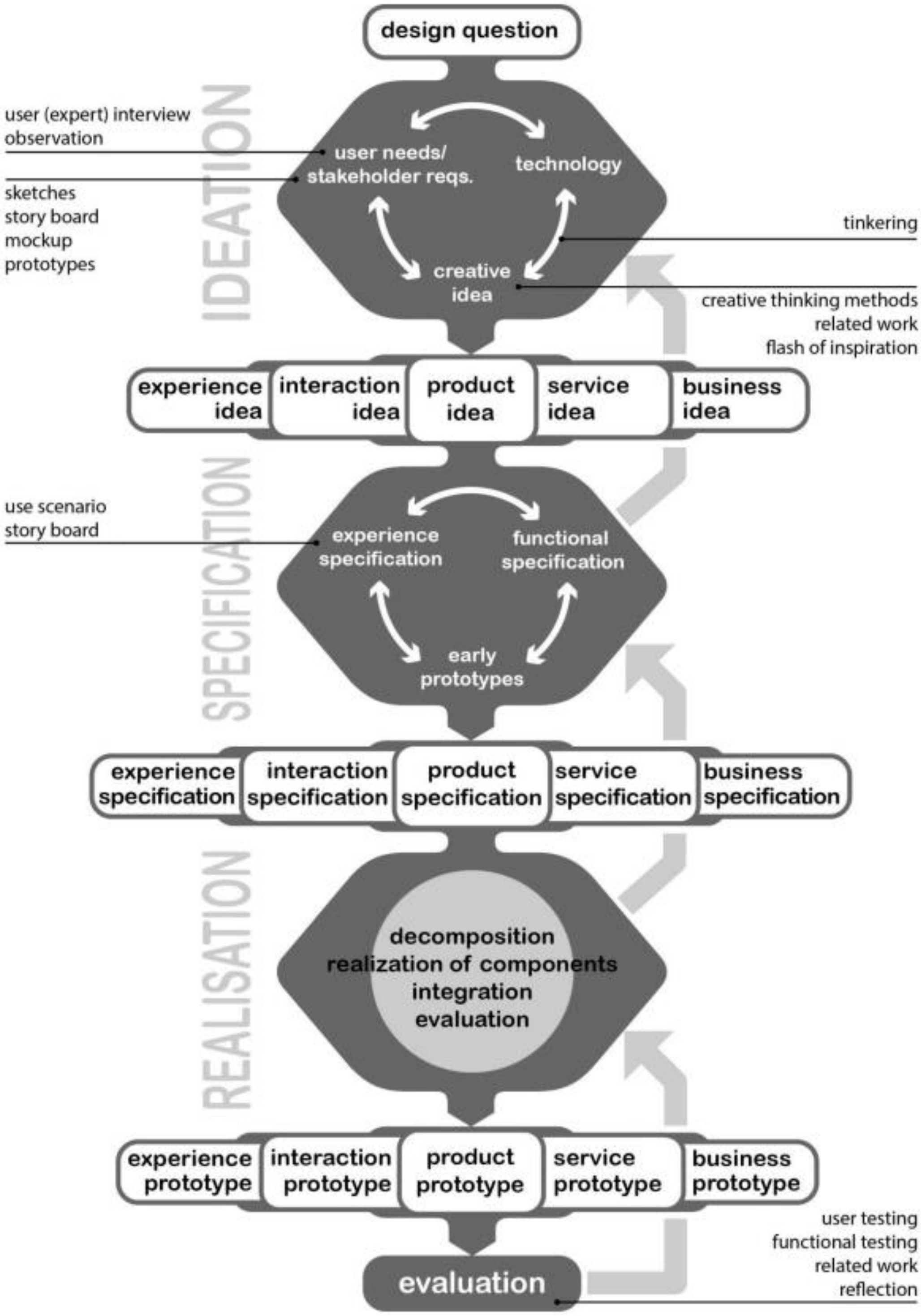


Figure 16 Creative Technology design progress

Source: adapted from [43]

3.2 Ideation methods

The goals of this phase are to identify the stakeholders, their interests and power, have good defined requirements and having some different concepts. First, a stakeholder analysis is performed using the literature research and research question described previously. With the help of the stakeholders, different requirements can be made and prioritized. Afterwards brainstorming, collage making and conceptualizing will be done.

3.2.1 Stakeholder analysis

To have a successful end product, the developer needs to understand more than just the user. All people that have a stake in the project should be studied. These people are called the stakeholders. Stakeholders can be individuals, groups or organizations. It needs to be clear which people are directly or indirectly influential to the product. In additional it is useful to know how much power and interest these people have during and after the design process.

The stakeholder analysis by Lucid Content team [44] is based on three steps: identify your stakeholders, prioritize your stakeholders and understand your key stakeholders. In the first step a list of all people who are affected or have a vested interest in its success or failure by the product should be developed. The second step the list of people will be prioritized by assessing their level of influence and level of interest. This will be done with a visual tool called the Stakeholder Power Interest Grid as can be seen in Figure 18. This grid is divided in four parts. In these part a stakeholder can be placed. The position will show the actions that should be taken to manage the stakeholders.

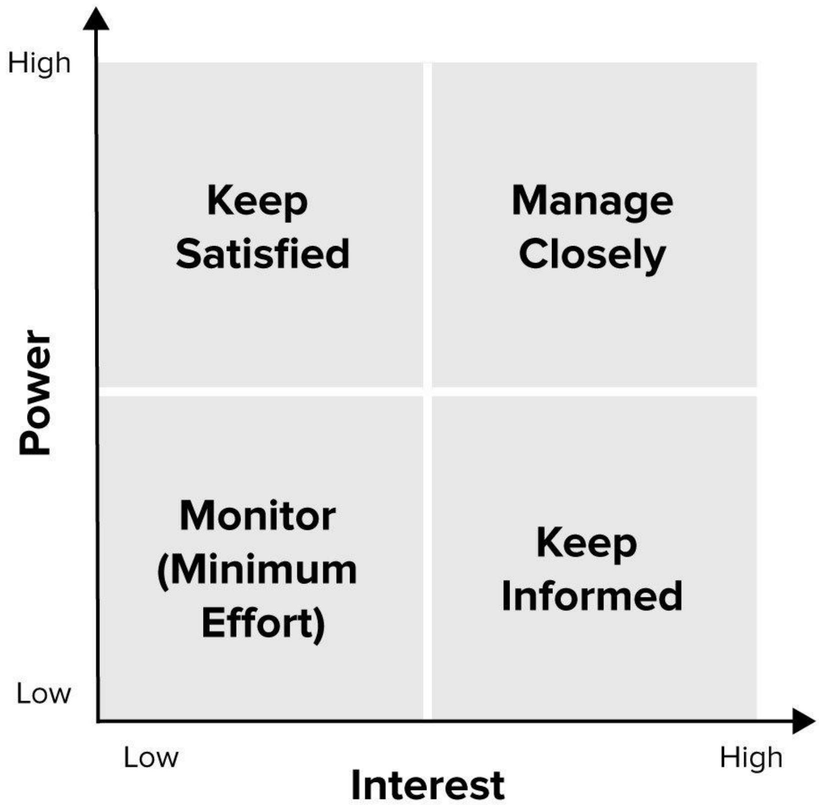


Figure 17 Stakeholders power grid

The final step is to understand the key stakeholder. This will be done by finding information about the stakeholder. A way to do this is by interviewing the stakeholder.

3.2.2 Requirement stating and prioritizing

Requirements are needed when developing a product. These requirements should be very clear and prioritized. Normally requirements come from multiple different stakeholders, and different stakeholders do have different weighted requirements. The most powerful stakeholders have requirements with more weight. The requirements are prioritized with the MoSCow method.

3.2.2.1 MoSCow

The MoSCow is a method to prioritize requirements by their importance. This method makes the importance clear in 4 different categories. The different categories are: *Must, Should, Could* and *Would*. *Must* is ta requirement that must be met. *Should* is a requirement that if possible should be implemented. *Could* is a requirement that, when implemented, does not effect the more important requirements (*Must, Should*). *Would* is a requirement that one would like to implement somewhere in the future.

3.2.3 Brainstorming

To generate a lot of ideas, brainstorming is a technique that can be used. One form of brainstorming is group brainstorming. Here multiple persons will actively interact with each other by talking and thinking about different ideas. All ideas are valid, and no idea can be criticized in this stage. In every idea can be some aspect that can be used. Individual brainstorming is almost the same as group brainstorming. However, here there is just one person that can fully focus on the topic.

In addition, during the brainstorm it is useful to sometimes muse off topic. A technique that can be used is 'Random connections'. Associations should be made to seemingly different concepts or objects, for instance in the room. Afterwards, these associations should be implemented to the problem that needs to be solved. An example that is given in the paper 'How to facilitate a brainstorming session: The effect of idea generation techniques and of group brainstorm after individual brainstorm' is:

> 'the problem at hand is to generate a new sun cream, and the random object chosen is a ballpoint pen. Associations can be generated from the ballpoint pen, such as writing, color, and roller. By connecting these associations to the sun cream problem, one might generate the idea of colored sun cream (i.e., the sun cream is changing color during application, showing level of absorption), a roll-on sun cream, or a roll-on sun cream containing colored sun cream.' [45]

3.2.4 Collaging

To come up with different ideas, collaging, i.e. mood boarding, can be used. By putting different pictures, drawings and sketches together on a slide or sheet, a collage is created. A collage can help one generate creative ideas. Different things on a collage can be: ideas that have been seen in life, other products with a similar vibe, photos, colors etc. Collaging is an easy way to put different useful images together. Afterwards, different concepts can be made.

3.2.5 Conceptualize

After stating the requirements, brainstorming and collaging, some main ideas will be created. These ideas should be made into multiple concepts. Concepts are more developed ideas that can be evaluated. This evaluation will be done with the help of the requirements. At the end of this phase, a single concept is chosen.

3.3 Specification methods

In the specification phase multiple tools will be used to specify the concept that has been chosen in the ideation phase, and a detailed description will be given. First, all interaction scenarios have been made to fully understand the interaction between the user and the product. Then, a level approach was made to describe the different systems and subsystems and their function.

3.3.1 Interaction Scenario

To get a better insight into the interaction between the user and the product an interaction scenario can be written. This piece of text describes every step a user takes and thinks about while using the product.

3.3.2 Functional decomposition with a level approach

To keep everything clear and understandable, an overview of the system is necessary. This overview can be created using a block diagram with different levels. The block diagram has two colors: black and white. The black boxes do not show the details of the system within the box. The white boxes do. This approach starts at level 0 . Level 0 gives an overview of every input and output of the system or product in relation to the outside environment. At this level, only black boxes will be used. In the next level, each black box is zoomed in on. This box will show again multiple black boxes of subsystems. This continues to more and more specific functions of the product. See Figure 19 below a schematic of this system.

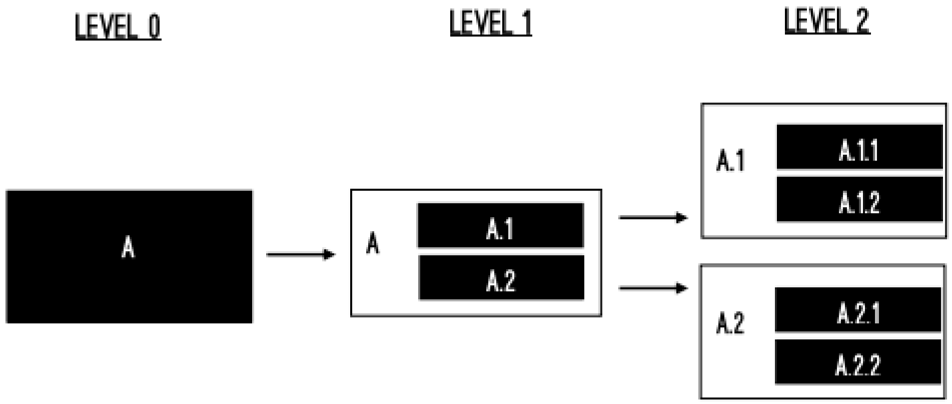


Figure 18 Example of a level approach

Source: adapted from [46]

3.4 Realization methods

During the realization phase, two methods were used. The first one is quick prototyping and the second is making a scale model. In this section, these methods will be explained briefly.

3.4.1 Quick Prototyping

In this report, quick prototyping means to make a prototype that is able to do the functions the product needs to do. This can be done with tools that are already in the workplace. The prototype should be used to test the functionalities.

3.4.2 Scale Model

A scale model is a smaller (or larger) version of the product being designed. In this report, it is used to give the audience an indication of the size of the product.

3.5 Evaluation methods

In the evaluation phase, two methods were combined to get the best results for this phase. First, a video was made to clearly show the idea of the product. Afterwards, a questionnaire will be used to obtain information from participants.

3.5.1 Video

Before the questionnaire a explanation video was made. This video includes a clear overview of the product and the concept.

3.5.2 Questionnaire

The program that is used for the questionnaire is Google Forms. This is an easy way to make a questionnaire and to send it out to the participants. Most questions allowed users to type out an answer, to get the most data.

Chapter 4 - Ideation

In this chapter the ideation phase will be described. The start of this phase is by doing a stakeholder analysis. Afterwards the requirements will be developed with the help of the most important stakeholders. These requirements are prioritized by a MoSCoW model. With the requirements the design space is made smaller and so brainstorming could be done more specific. Brainstorming is the next step. Resulting in 6 different concepts. These 6 different concepts are presented and 1 one of this concepts is chosen. In the remainder of this chapter, the reason of choosing this concept will be explained.

4.1 Stakeholder analysis

The stakeholders of this project are listed below. These stakeholders are people or groups that are affected or have a vested interest of the project.

- Richard Bults, Kasia Zaleskwa (Clients)
- University of Twente (Project supervisors, Kasia Zaleskwa & Richard Bults)
- Tiny House Community

To prioritize the stakeholders a power interest grid is made and presented in Figure 20. The position of the stakeholder on the grid shows how closely this stakeholder should be managed. In addition the location shows how much power and how much interest the stakeholder have. In the right upper corner the stakeholder has a high power and is highly interested. These people needs to be fully engaged and satisfy. The left upper corner are the stakeholders with a lot of power but no interested in the project. These people should be satisfied but not fully engaged. In the bottom right are the people with low power but a high interest in the project. These people should be adequately informed and should be ensured that no major issues will be arise. The left bottom are the people with no power and no interest. These people only should be monitored.

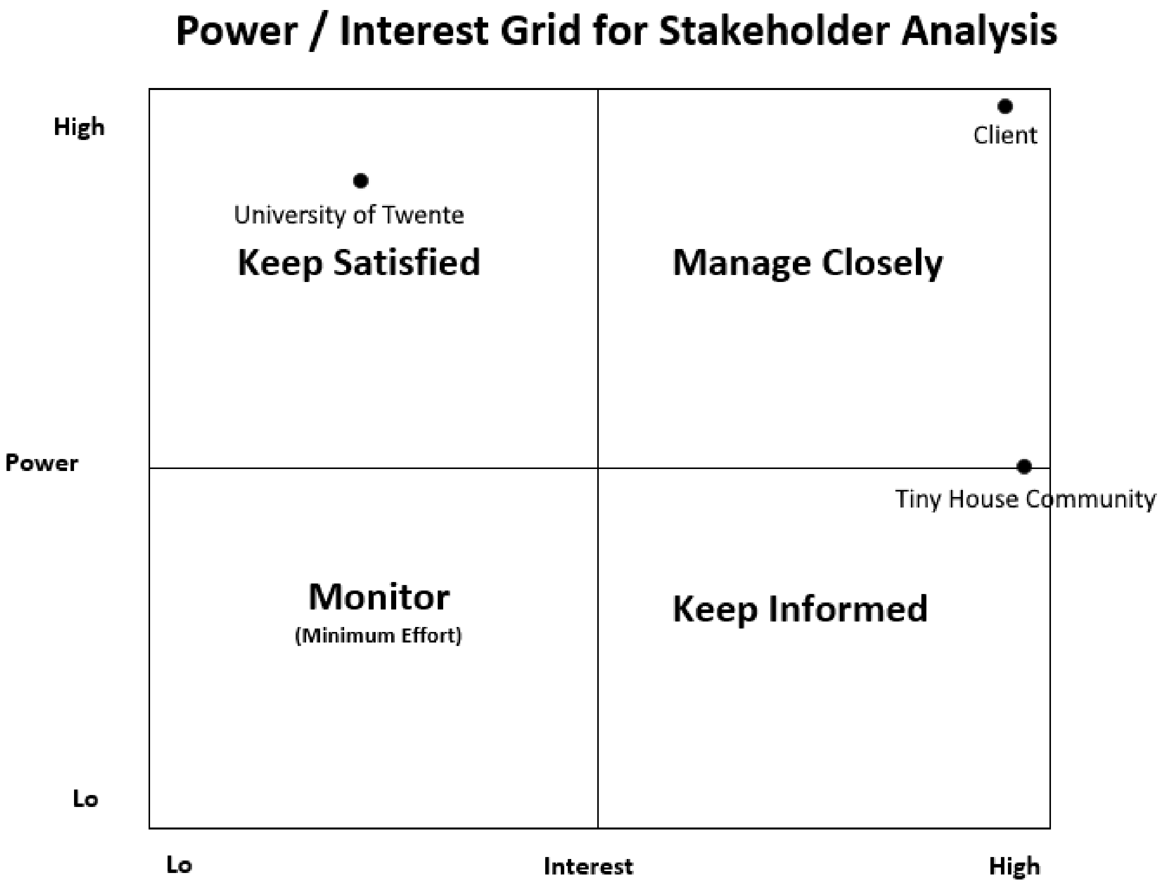


Figure 19 Power matrix grid stakeholders

4.1.1 Clients

The main stakeholders of this project is the client. This client is represented by Richard Bults and Kasia Zalewska. The client is considered the biggest decision makers. This makes them very powerful and highly interested. For this reason they are positioned in the upper right corner of the grid. Richard Bults is the supervisor of the project and is a expert on the rainwater buffering systems of the University of Twente. He can provide a lot of insights to this topic. In addition he shows a lot of affection with the project and is a decision maker. Kasia Zalewska supports the project in a way as a client. She thinks about the social aspects as a user in regard to the development of a solution. She helps to make the product good the for environment and consumer. She is also a decision maker.

4.1.2 Tiny House Community

The Tiny House Community is a important stakeholder due to the fact that they are the target group for the product. The product should be designed to their liking. At the end, they will buy the product. This is the reason why they are put again the right upper box. However they are a bit lower then the client due to the fact that they are not specific enough in their interests, so their power is lower. This stakeholder does not have one representative. By studying and communication with this stakeholder a lot of insight for the product will be generated. In addition the Tiny House Community are also decision makers. They decide what size the Rainwater Catchment Area should be.

4.1.3 University of Twente

The University of Twente is another decision maker. The University of Twente is represented by Richard Bults and Kasia Zalewska as supervisors. They will lead the project in the way so that the University will accept the project. The project should be of a specific academic level. In addition the University of Twente helps to provide the project with materials. They are the supervisor of the project so they need to be satisfied. For that reason this stakeholder is put in the left corner.

4.2 Requirements from Clients stated using MoSCoW method

After different brainstorm sessions with the client. A clear vision was made. This vision was translated to a requirement list that is categorized by the MoSCoW method. The list can be seen in Table 5 .

The product must be fully water sufficient for a Tiny House household of 2 persons. This means that the surface area should be minimally 60 square meters as can be seen in Chapter 2. Furthermore the product needs to be easy to use so that the user does not need to spent a lot of time by setting it up. In addition the product needs to be very low in maintenance, again to spare the time of the user interacting with the product. The product will be used outside and needs to collect rainwater, for that reason it needs to be resistant to Dutch weather. Lastly, the product must be environmental friendly.

The product should be autonomous in its function to again spare the user time. The product is made for Tiny House owners, these people do not want pay a big portion of the value of their home for a product that collects rainwater. For that reason it should be affordable (3000-5000 euros). In addition a Tiny House that is fully off grid, will be also generating its own energy. The energy is scarce. Hence, the product should be Self Supporting or low energy use.

During the brainstorm no Coulds or Woulds were stated.

Table 5 Client Requirements

Must
Easy to setup and tear down
Easy to use
Very low maintenance
Fully support water consumption of a Tiny House household of 2 persons
Resistant to Dutch weather (up and including 'Code Yellow'
Environmental Friendly
Should
Autonomous in its functioning
Affordable (3000 - 5000 euros)
Self Supporting Energy

4.3 Collages

Collage were made to get creativity flowing. In total there were 7 collages developed. These different collage have different themes. The themes were created during the brainstorms and redeveloped in time. However not every theme led to one concept. Sometimes different themes were used for one concept. All sources can be found in Appendix A.

The first theme is stability with air. The collage can be seen in Figure 21.

Figure 20 Collage 1 Air stability

Stability with air could be a way to make a easy to setup rainwater catchment area. In the same way as pools and tents are easy to setup. The other pictures in the collage is an unstoppable robot [47] and this could be a way to deploy and pull back the rainwater catchment area.

The second theme is 'flasher origami'. The collage can be seen in Figure 22

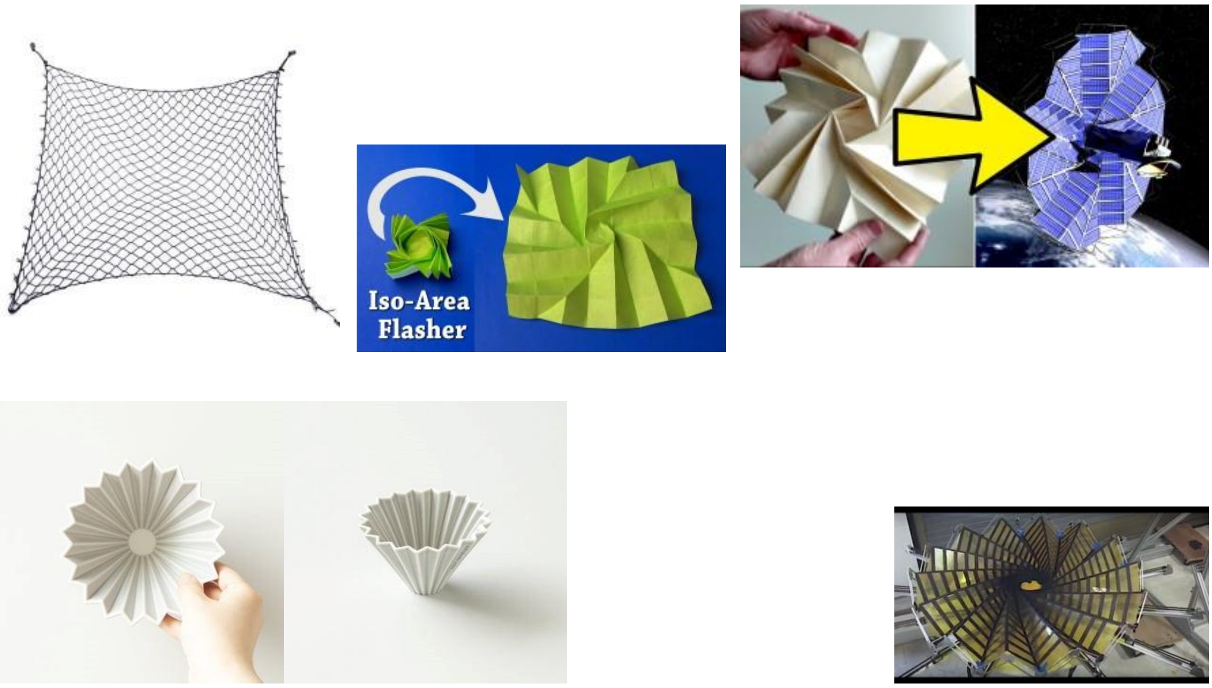


Figure 21 Collage 2 Flasher Origami

This theme was already researched during the literature review. Origami can used to pack up big surfaces into small packages. The flasher type of origami is the most useful for this application. The reason for that is that it folds into a small cylinder form a big surface.

The theme of the third collage is keep out rain/sun. The collage can be seen in Figure 23.

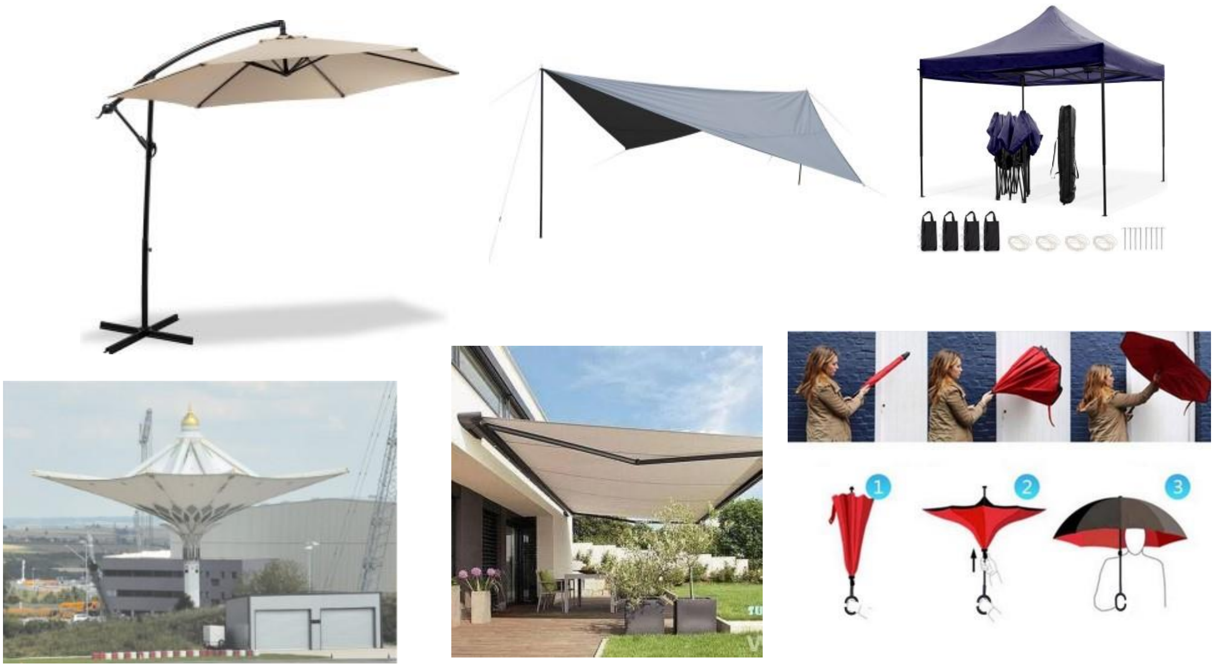


Figure 22 Collage 3 Sun/Rain wearing

The theme was thought about that if it is possible to keep out the rain or the sun. It is also possible by reversing the mechanism to collect the rainwater.

The fourth collage theme was how to get energy. This can be seen in the Figure 24 below.

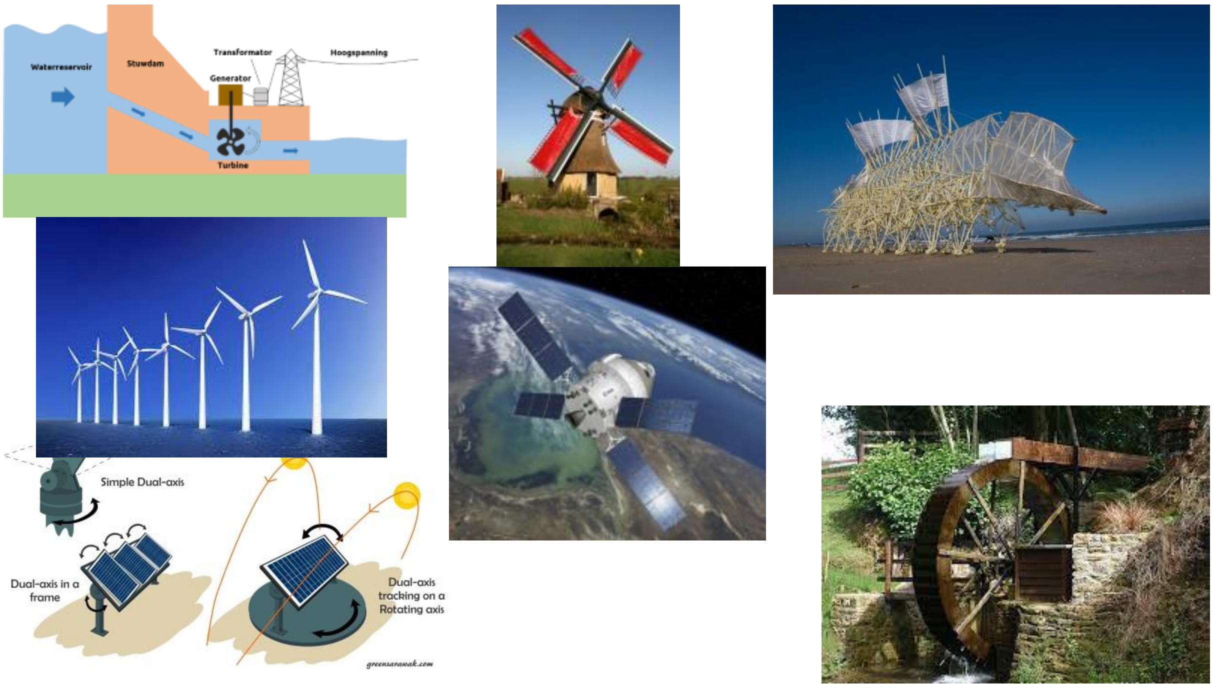


Figure 23 Collage 4 Energy

For the Tiny House community, green energy is important. Also if you want to be fully off grid the Tiny House owner needs to generate his or her own energy. If the rainwater catchment area needs energy it should generate there own energy. In the collage some examples are given.

If the product uses almost no energy it does not have to generate its own energy. So the Theme of this fifth collage is action reaction. This collage can be seen in Figure 25.

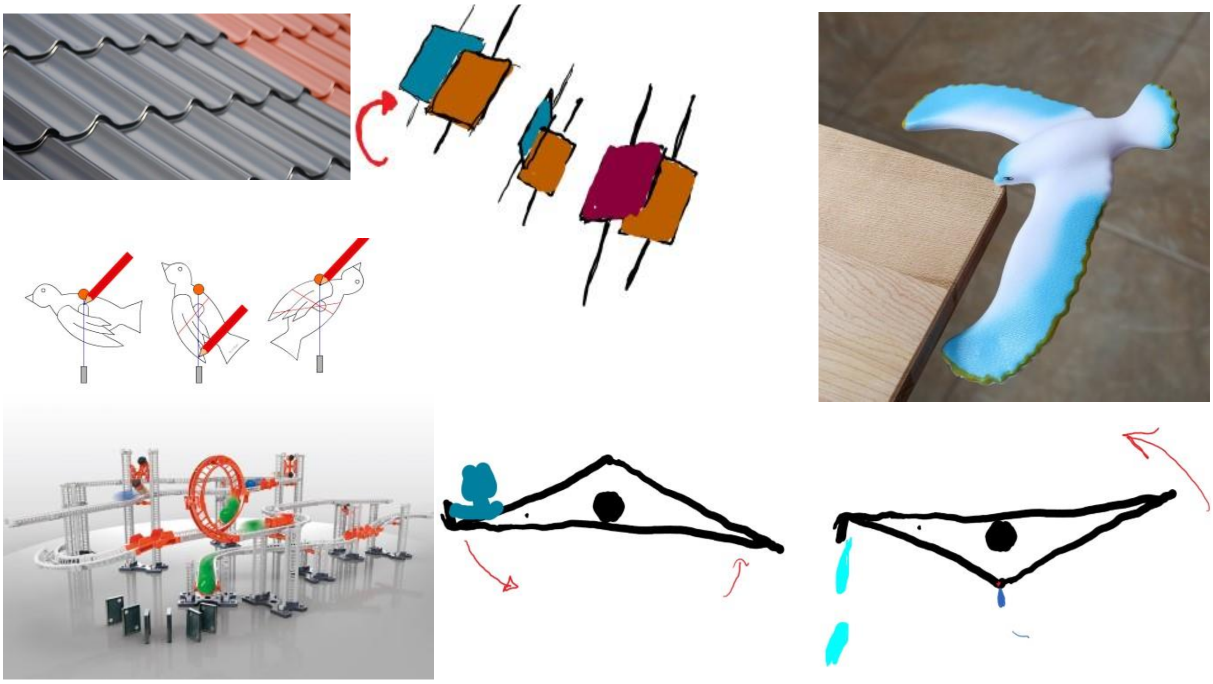


Figure 24 Collage 5 action reaction

With the help of the center of mass of a object and its center of rotation big objects can be moved without a lot of energy. This can be seen on the right of the collage. On the left shows some way that movement of one object can move another so that it is more efficient.

The sixth collage theme is about cleaning areas. This collage can been seen in Figure 26.

Figure 25 Collage 6 Cleaning areas

Most of these pictures can be used to clean a surface. This can be a living room, pool or stable. Moss could be a natural filter to clean the water.

The seventh collage theme is about cloths. This can be seen in Figure 27.

Figure 26 Collage 7 Cloths

This theme is chosen because of the weather proof material that is used to leave rain outside or to catch wind. This material can be used to catch rain. The left picture shows a roll system for the jib sail.

4.4 Concepts

Multiple different concepts are created. These concepts came together with the help of brainstorm with different people from different backgrounds. The concepts are created by the help of a collage. These collages where based on existing products and themes that could help in implementing one or multiple requirements. After the collages where made different good aspects of the products were put together into a concept that fulfill as much requirements as possible. In the Figure of every concept requirements can be seen as well as if they are met. The sources of the pictures that are used can be found in Appendix X.

In total there were 6 concepts developed. The first 5 are based on the idea that the catchment area should be only 'opened' when it rains. Hence, the chance to get polluted will be decreased. The last one is based on cleaning the catchment area after every use. All the concepts will be equipped with a controller. This micro controller will be connected to the Internet and 'Buienradar'. This will make the product autonomous because it knows when to open the product to collect water without the help of a human being.

4.4.1 Concept 1

The first concept is based on a motorized pergola cover. As can be seen in the top right of Figure 28. This product is used to block the sun when it shines on the veranda. In addition it can also be closed when it rains. So that people still can sit outside during the rain. This specific function led to concept 1. To keep the catchment area as clean as possible it should be only available when it rains. The rest of the time it should be closed, so that it can not get dirty. No leaves, insect, dust, etc. will be able to fall on the catchment surface. At concept 1 this is done by the effect of flipping the lamella. Also instead of laying the catchment area flat, it should be tilted to form a slope (5 – 90 degrees). This will give enough run off to collect the water. The requirements that the concept fulfill are stated in Table 6.

One of the biggest advantages of this concept 1 is when something falls on the catchment area during the rain storm it can be fall through the surface when the lamella is put vertical. This can be seen in the left corner of Figure X. If it sticks, the lamella could be shaken to shake off even more trash. Another advantage is that this concept is fully self sufficient if the other side of the catchment area will be solar panels. This will generate energy when the sun shines and the solar panel side faces the sun. When the sun goes away and it start to rain the system turns around so that the catchment area side will be facing the air to collect the water. In addition this concept is very easy to use because it will be fully autonomous and almost no maintenance needs to be done.

The problem of this concept is that it is not yet easy to setup or tear down. It should able to withstand Dutch weather and so it should be built sturdy. This will lead to big heavy materials. Furthermore the catchment area should be 61 squared meters to support a 2 persons household. This will make for a really big veranda but that would not really be a solution.

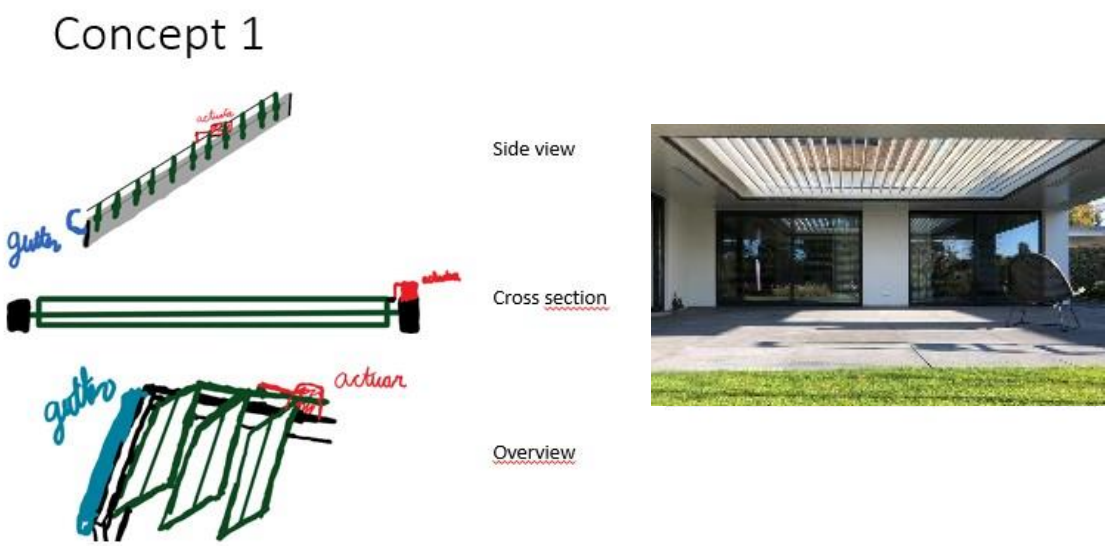


Figure 27 Concept 1

Table 6 Concept 1 requirements

Must	Required?
Easy to setup and tear down	Not yet
Easy to use	Yes
Very low maintenance	Yes
Fully support water consumption of a Tiny House household of 2 persons	If min 60 m2 yes
Resistant to Dutch weather (up and including 'Code Yellow')	Depends
Environmental Friendly	Depends
Should	
Autonomous in its functioning	Yes
Affordable (3000 - 5000 euros)	Depends
Self Supporting Energy	Depends

4.4.2 Concept 2

The second concept is based on a parasol and umbrella. Both have the same sort of mechanism in them, the only difference is there functionality. The parasol keeps out the sun and brings shade in the garden. The umbrella keeps a persons dry. Concept 2 will do exactly the opposite of these two functions. It will be catching the rain and when it is dry it will be closed. Again as the same in concept 1, the catchment area will be most of the time closed so that dirty stuff can not fall on the catchment area. The concept will be opened until the surfaces have a certain slope. Concept 2 can be seen in Figure 29. The requirements that the concept fulfill are stated in Table 7.

An advantage of this system is that it is easy to set up and tear down. It only needs to be dug down into the ground. In addition it will be fully autonomous and low maintenance because of this the concept is easy to use. Sometimes it should be cleaned. Furthermore this concept can be easily scaled down. This can be nice for other groups such as people that lives in a van.

Disadvantages of this concept is that it is not self sufficient and to make a minimal catchment area of 60 squared meters the pole of the umbrella will be 4.4 meters high. The height is measured with the help of the radius of a circle. To get a minimum circle area of 60 squared meters the radius should be 4.4 meters.   This can be a disadvantage for when the product will be moved. Or can not be allowed by the municipality because of its height. In addition umbrella and parasols are not good in strong winds, these can easy be blown away. This concept will not succeed the Dutch weather .

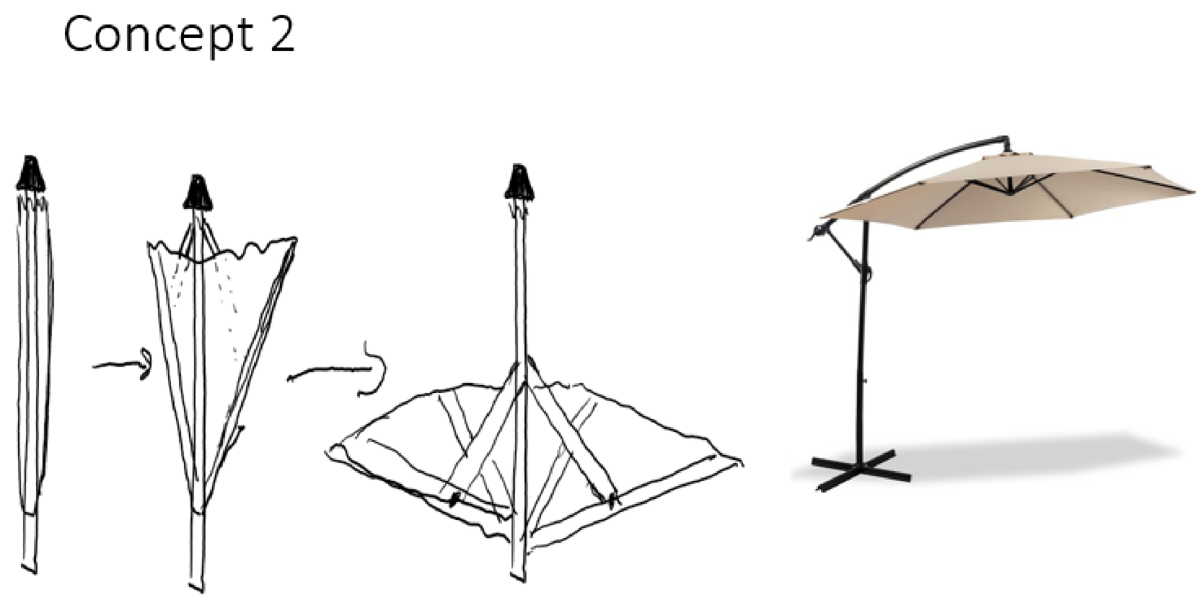


Figure 28 Concept 2 Umbrella

Table 7 Concept 2 Requirements

Must	Required?
Easy to setup and tear down	Yes
Easy to use	Yes
Very low maintenance	Medium
Fully support water consumption of a Tiny House household of 2 persons	If min 60 m2 yes
Resistant to Dutch weather (up and including 'Code Yellow')	No
Environmental Friendly	Depends
Should	
Autonomous in its functioning	Yes
Affordable (3000 - 5000 euros)	Depends
Self Supporting Energy	Depends

4.4.3 Concept 3

Concept 3 is divided into two similar ideas. The idea is that next to the Tiny House is a system that fold/blows out when rain is expected. When the rain is over it should be pulled or fold back into the storage part of the system. Concept 3A is based on a inflatable pool. This pool can be seen in the right corner of Figure 30. A pool has an inflatable side that is pretty sturdy. Also a pool just collected rainwater normally. The concept should be able to inflate and collects water and when the rain stops should be pulled back by a cable. Again this concept will be only open during the rain and so the chance that something polluting will be caught is way smaller. The requirements that the concept fulfill are stated in Table 8.

The advantages of this concept are that it is easy to set up and tear down. The inflatable side will be rolled up and the rest of the system will be made of light plastics so that it is as easy as a inflatable pool to setup and tear down. Plastic is a cheap building material so the product can be made affordable. This concept is fully autonomous and for that reason easy to use. However it depends on how the concept is made if it is environmental friendly and resistant to Dutch weather.

Some disadvantages of the concept are that it is not self sufficient and a lot of energy is used for the inflatable ring to stay fully solid. In addition the catchment area will not fold nice and clean back into the system. This can result in a big mess. With this disadvantage in mind concept 3B is made.

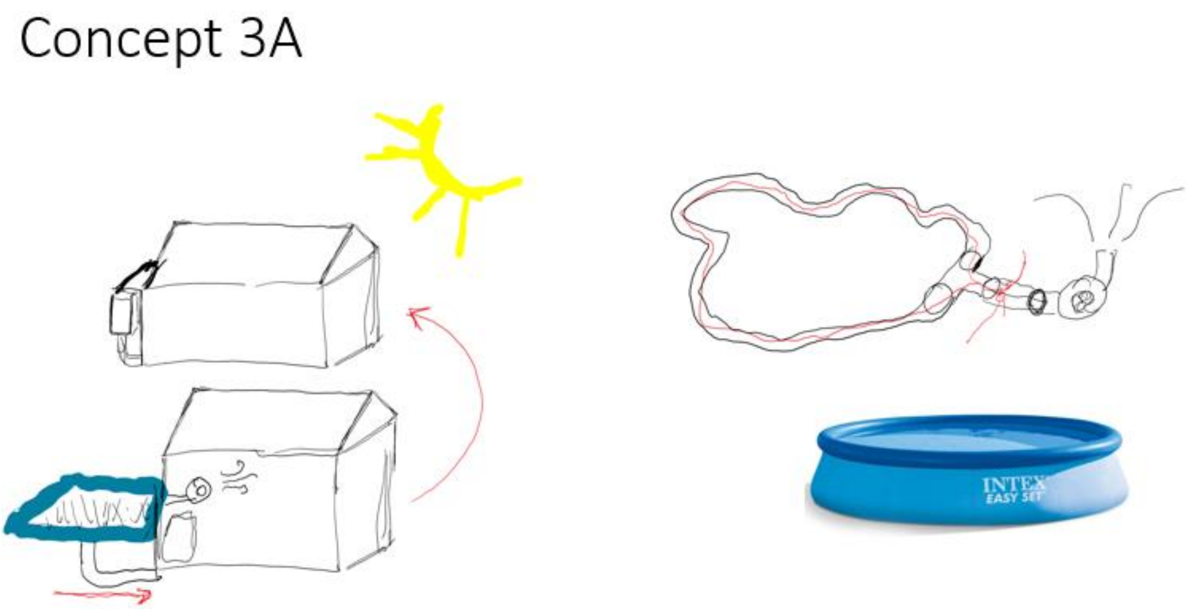
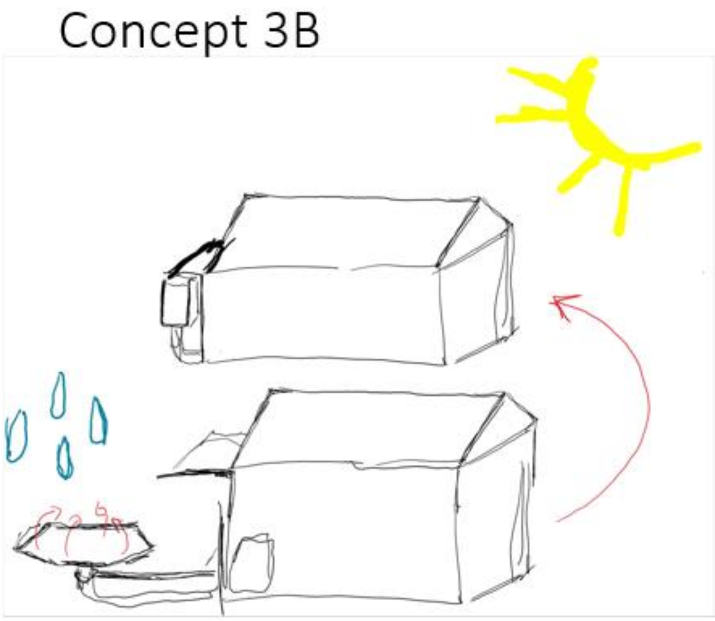


Figure 29 Concept 3A

Table 8 Concept 3A requirements

Must	Required?
Easy to setup and tear down	Yes
Easy to use	Yes
Very low maintenance	Medium
Fully support water consumption of a Tiny House household of 2 persons	If min 60 m2 yes
Resistant to Dutch weather (up and including 'Code Yellow')	Depends
Environmental Friendly	Depends
Should	
Autonomous in its functioning	Yes
Affordable (3000 - 5000 euros)	Yes
Self Supporting Energy	Depends

Concept 3B will do exactly the same as 3A. However the mechanism that folds out is different. Here a flasher origami is used to make it as efficient as possible. This type of origami is also used by NASA in for instance the 'Starshade'. A prototype of the Starshade can be seen in the right upper corner in Figure 31. By using this foldable system the disadvantage of getting mess, is not there anymore. In addition it can be made much stronger so it could resist the Dutch weather more easily. However the costs of the product will increase. The requirements that the concept fulfill are stated in Table9.



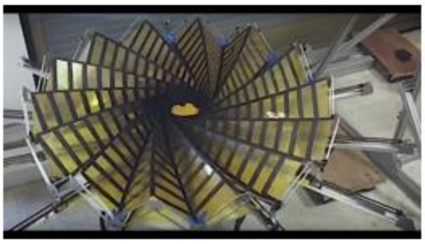


Figure 30 Concept 3B

Table 9 Concept 3B requirements

Must	Required?
Easy to setup and tear down	Yes
Easy to use	Yes
Very low maintenance	Medium
Fully support water consumption of a Tiny House household of 2 persons	If min 60 m2 yes
Resistant to Dutch weather (up and including 'Code Yellow')	Depends
Environmental Friendly	Depends
Should	
Autonomous in its functioning	Yes
Affordable (3000 - 5000 euros)	No
Self Supporting Energy	Depends

4.4.4 Concept 4

The fourth concept is based on a party tent and pool cover. As can be seen in the top right corner and the bottom left corner in Figure 32. While other concepts uses a surface area that folds in and out, in this concept the surface area will be always there. First the user should setup a sort upside down party tent. This just needs to be done once. Afterwards an automatic tarp will cover this 'party tent' so no contamination can be caught by the catchment area. When it begins to rain this tarp will be rolled up so that the catchment area can harvest rainwater. This will lead to a more cleaner catchment area then for instance a roof. The requirements that the concept fulfill are stated in Table 10.

The advantages of this system is that it can be made fairly cheap because both of these products are not expensive. In addition just a light cover needs to move instead of the whole catchment area. This makes the product less energy consuming and is beneficial for the Tiny House owner. If a form of renewable energy will be generated this product will be self supported. Furthermore the product will be autonomous and for that reason easy to use for the user.

Disadvantages of this system is that when something fells into the catchment area still the consumer should clean the area. Thus it needs a bit of maintenance. In addition the 60 squared meters are always in use so this piece of land can not be used for anything else. Furthermore the product should be build very strong to withstand the strong winds of the Dutch weather.

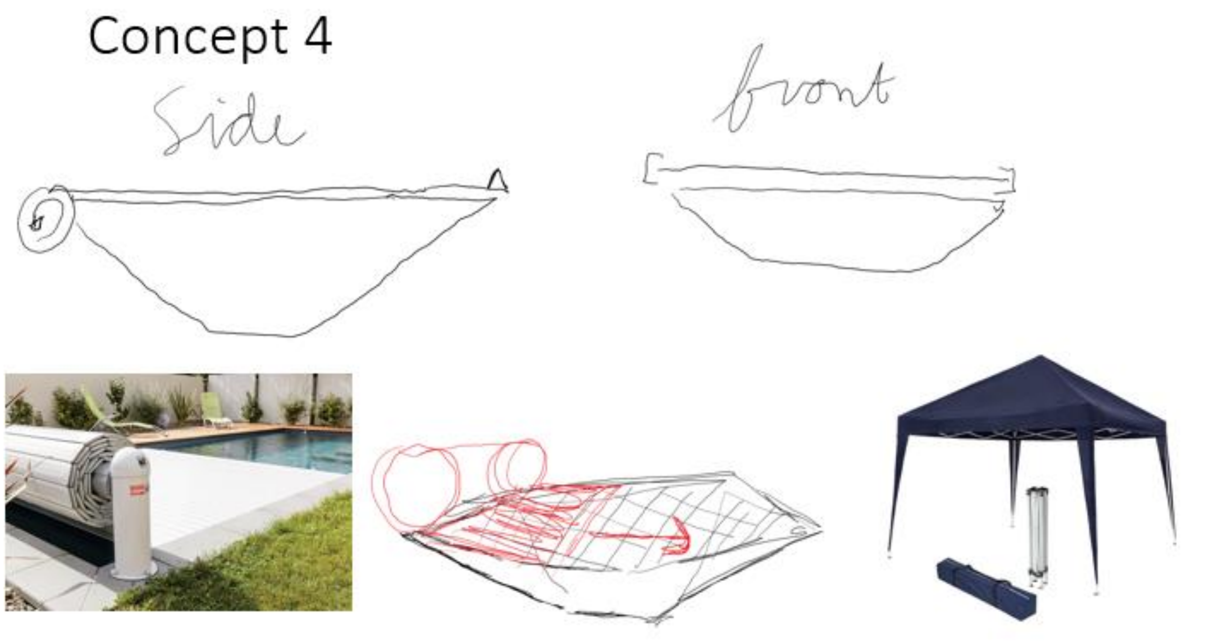


Figure 31 Concept 4

Table 10 Concept 4 requirements

Must	Required?
Easy to setup and tear down	Yes
Easy to use	Yes
Very low maintenance	Medium
Fully support water consumption of a Tiny House household of 2 persons	If min 60 m2 yes
Resistant to Dutch weather (up and including 'Code Yellow')	Depends
Environmental Friendly	Depends
Should	
Autonomous in its functioning	Yes
Affordable (3000 - 5000 euros)	Yes
Self Supporting Energy	Depends

4.4.5 Concept 5

The fifth concept is based on a different approach of harvesting as clean as possible rainwater. The first four were based on a catchment area that is not always into the open air but only opens or is useful when it rains. This concept is based on a surface are that cleans itself. With the help of collage six this concept is developed, see Figure 33. The theme of this collage was 'cleaning areas'. This concepts is cleaning each time the area. The requirements that the concept fulfill are stated in Table 11.

Advantage of this catchment area is that it does not need any maintenance of the consumer. The product cleans itself and will get the cleanest rainwater as input. The rotation can be formed by the help of a windmill and so it will be self sufficient. Furthermore the system will be autonomous and so very easy to use.

Disadvantages of this concept are that the system is a really big mechanic machine. This potentially gives complications such as weight and really hard to tear down and set up. To take this concept with you to a new place will be almost impossible. Also this will be very expensive to built. In addition it depends on how it is build if it can resist Dutch weather and if it is environmentally friendly.

Concept 5

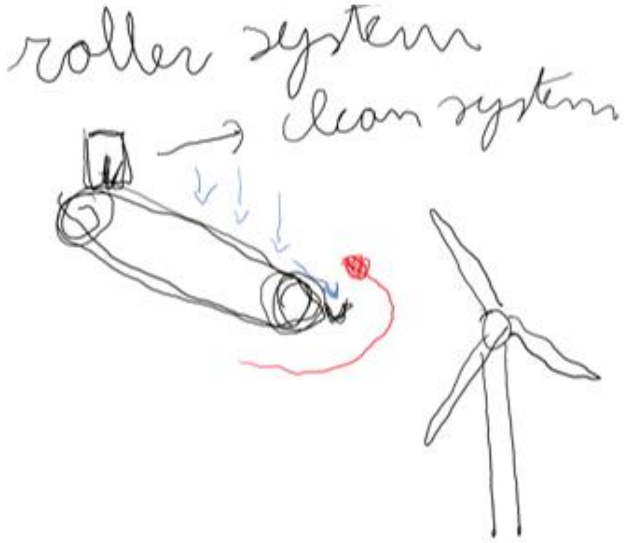


Figure 32 Concept 5

Table 11 Concept 5 requirements

Must	Required?
Easy to setup and tear down	No
Easy to use	Yes
Very low maintenance	Medium
Fully support water consumption of a Tiny House household of 2 persons	If min 60 m2 yes
Resistant to Dutch weather (up and including 'Code Yellow')	Depends
Environmental Friendly	Depends
Should	
Autonomous in its functioning	Yes
Affordable (3000 - 5000 euros)	No
Self Supporting Energy	Depends

4.4.6 Concept 6

The six concept is based on a jib sail of a sailboat. This sail should be easy to set up and tear down and should catch wind. The concept should catch rain instead of wind and this is done by putting the sail in an angle instead of up right. With the help of collage 7 this concept is made the theme of this collage was cloths. One of the pictures was a jib sail. The concept can be seen in the Figure 34. In the Figure only 2 sails can be seen. However there will be 4 sails so that a full square catchment area will be created seen from above. The requirements that the concept fulfill are stated in Table 12.

The advantage of this system is that it is very easy to use and easy to set up and down. In addition it will be low maintenance because of the fact that the system is only open when it rains. This leads into lower amount of pollution on the catchment area. Furthermore the system will be autonomous and can be made affordable. Furthermore a jib sail is made to be good against strong winds. This will lead to the concept being resistant to Dutch weather. If the concept is made with old sail boat materials it will be an up cycling way to use the materials and so it will be environmental friendly.

The disadvantage of the system is that it is not yet self supporting. It will not generate energy and it will use energy to roll up the sail and to open it. Also there is not yet a way to collect the water in some sort of gutter.

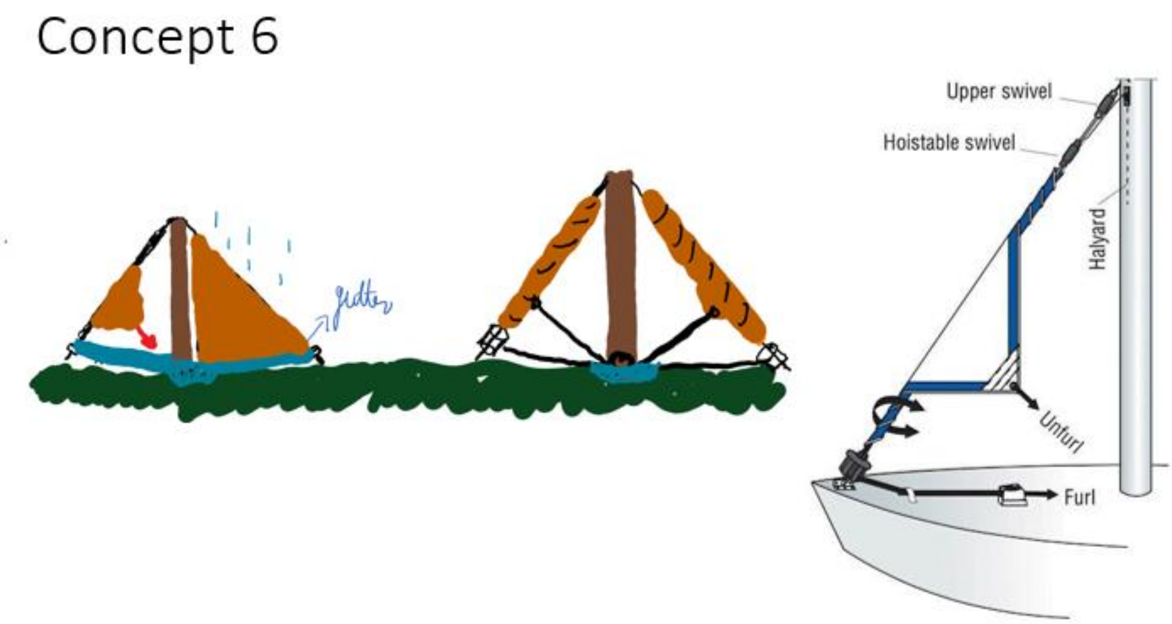


Figure 33 Concept 6

Table 12 Concept 6 requirements

Must	Required?
Easy to setup and tear down	Yes
Easy to use	Yes
Very low maintenance	Yes
Fully support water consumption of a Tiny House household of 2 persons	If min 60 m2 yes
Resistant to Dutch weather (up and including 'Code Yellow')	Yes
Environmental Friendly	Depends
Should	
Autonomous in its functioning	Yes
Affordable (3000 - 5000 euros)	Yes
Self Supporting Energy	Depends

4.4.7 Chosen Concept

Concept 6 is chosen due to the fact that it fulfills almost all requirements. The other concepts all have more cons than Concept 6. Still, some of the requirements are dependable on the execution. The dependency environmental friendly is easy to solve. A lot of materials can easily made of recycled material. The sail can be made of old sail boat sails. Other materials can also be recycled by an old boat such as the roller system and the lines. The post can be made of aluminum. The self supporting energy requirement will be hard to fulfill. However it is always possible to put solar power next to the concept.

Chapter 5 - Specification

In this chapter the chosen concept (section 4.4.7, concept 6) will be fully specified. First a detailed description will be given with more in depth design. Secondly, a persona will be developed and an detailed interaction scenario will be described to fully understand which functions the Rainwater Catchment System (RCS) needs. Afterwards, the system will be investigated with the functional decomposition. Finally, functional requirements and non-functional requirements will be stated.

5.1 Detail Description

The final concept for the rainwater catchment system was ideated in the previous chapter. The design main components are the pole, the sail and the gutter see Figure 37. There are still some components, the components that will collect the water after the gutter, a component makes able to be only open when it rains and components that secures the pole from falling down.

This design will lead to a fully provided rainwater source and be fully automatic. The interaction with the user will be as minimal as possible. The user needs to set up the system once when they settle at a new place with their Tiny House. It should be attached to the rest of the rainwater harvesting system and connected to the internet. Afterwards the RCS should be fully automatic. However the user still needs to be able to turn on and off the RCS with a push of a button. In addition, there should be an emergency button. This leads to that the user is fully in control of the RCS.

The material of the sail will be water repellent so that water can easily run off to the gutter of the RCS. This sail can be from a recycled material, for instance an old jib sail of a boat. The ground area should in total be 60 m2. However in the picture 36 below only one and two sails are shown but this will be 4 different sails in all 4 directions. Another sketch of the RCS can be seen in Figure 35, here the system is rolled up, thus closed. Again this is just one sail for a clear understanding. However, the RCS will be 4 sails.

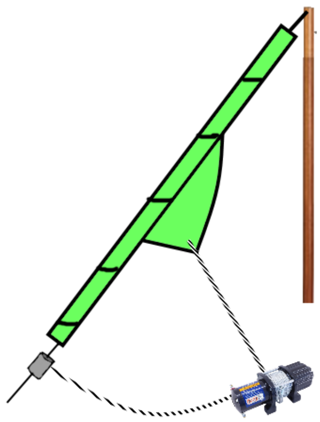


Figure 34 rolled up design RCS

The following Figure, Figure X, is the system again. However this time the system is open and ready to collect water.

1. Roll system
2. Sail
3. Actuator
4. Pole
5. Turning point
6. Line (Guy line)

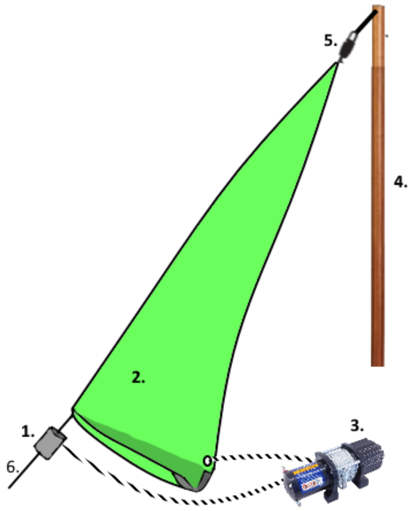


Figure 35 rolled down 2 sails design RCS

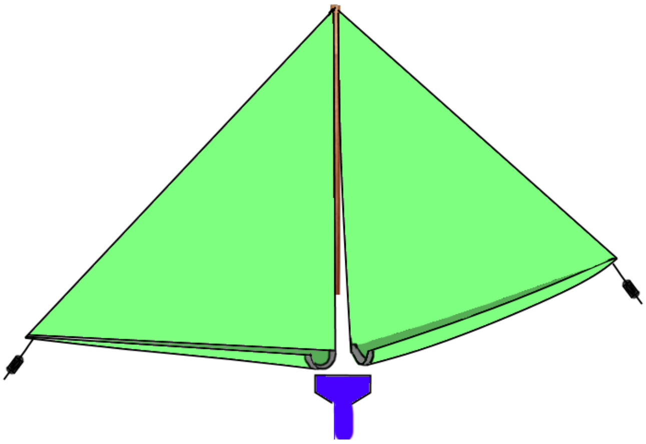


Figure 36 rolled down design RCS

To get to a ground surface of 60 squared meters and the height of the pole should be a minimal of 1.05 meter. The sail total surface of the 4 sails together will be 62.9 squared meters. These dimensions can be found in Figure 38 below. A 15 degrees angle is chosen for a good run off and handy size pole to work with.

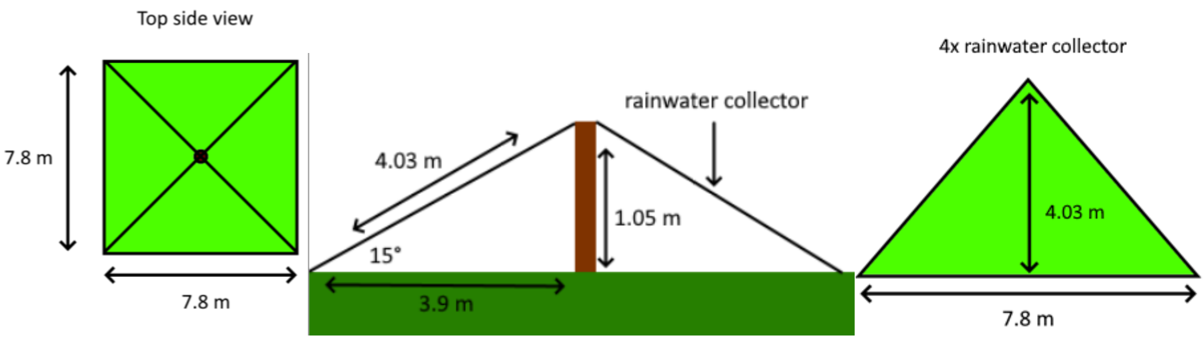


Figure 37 Dimensions RCS design

5.2 Persona and interaction scenario

To get a clear insight of how the user will interact with the RCS and to make the functions more visible of the RCS a persona and interaction scenario is created. The persona is based on talks with my clients and stakeholders and by using Facebook to identify different Tiny House owners and their interests. The persona is then used to give a in-depth interaction with a person and the RCS.

5.2.1 Persona: Tiny House owner

The Tiny House owner is the most important stakeholder as they are the owner and user of the RCS. Tiny House owners are really adaptable to changes. They want to be as environmentally friendly as possible and are able to give up some of their luxury for the goal. Most of the times the owner of a Tiny House have already a way to get water or have thought about it. However not a fully good solution is yet provided. In addition Tiny House owners are self conscious about their water usage and electricity.

The persona of Eric Tilleman has been created in the same free spirit way for living fully off grid. This is one of his goals. In addition, Eric also wants to be fully self supporting and be environmental friendly. Some barriers that Eric needs to face are real barriers Tiny House owners got. The information is gathered by research on a facebookgroup called Tiny House Nederland [48].

General Data:

Eric Tilleman, 35 years old, lives together with Mara Grootjes (33 years old).
A child care worker at childcare organization, Assen.
Education: cultural-social education at The Hague University of Applied Sciences, The Hague.
Living in Grolloo in a Tiny House for 5 years, Drenthe.

Figure 38 Portret picture of Eric Tilleman

Source: adapted from [49]

Goals: are to make his Tiny House as self-sufficient as possible. To live as freely as possible, without restrictive rules that have a negative influence on his choices for his home. His idea of self-sufficiency currently focuses mainly on the water supply, so that he is not dependent on the fresh water infrastructure of the place where his Tiny House is located.
He also wants to live as sustainably as possible. This influences his choices for, among other things, the materials of his home, his modes of transport, his ability to grow vegetables himself and human and animal friendliness.

Personality: Eric is aware of the consequences of his choices, not only for himself but also for the future of the Earth. However, he gives himself the freedom to make use of the options that are available.
Eric has a naturally curious attitude to life. That is why he is always open to even better or more sustainable solutions that are available.

Barriers: There are three barriers to the water system Eric uses now. Most of the trouble is caused by the stench that comes from the water. This means that the water is not clean enough to function as drinking water. The surface of his water depot on the roof is not large enough to meet his daily water needs. And last but not least: municipal regulations and bureaucracy prevent Eric from developing his ideas about self-sufficiency further.

Bio
Eric met his wife Mara at the Festival Sziget in Hungary as a 25-year-old young man who had just graduated college. Together they soon made plans about their way of living, working and housing. Five years later, they bought their first Tiny House, where they still live. They moved 3 years ago from Hooghalen to Grolloo. In Grolloo there are more possibilities for natural and sustainable living, with fewer people around. Eric and Mara have a plot of 350 square meters. There is room for a vegetable garden, a small orchard and they rent an adjacent meadow from the municipality where they have some chickens and an elderly donkey to roam around. In their spare time, they spend a lot of time gardening, maintaining their plot and house and taking care of the animals. Eric is also a member of

the Drentse Buitenboeren Foundation. There he finds like-minded people who want to optimize the sustainability of Drenthe. Twice a year he organizes an outdoor activity day for the children at the childcare organization where he works so that they too can become more aware of sustainable living. Eric has installed a new water supply for his Tiny House; The RCS.

Words that suit Eric:
Energetic
Socially concerned
Curious
Busybody
Creative

5.2.2 Interaction scenario

To fully understand the interaction with the user and the RCS, an interaction scenario is written in part of text below. In this text all interactions that will occur with the RCS will be showed in a storyline. Knowing all the interactions functional requirements can be made. This will be done in section 5.4. The persona helps to make the scenario more realistic and the scene of the text more clear. The scenario is based on the concept 6 in Chapter 4 and knowledge that is collected by talking the stakeholders.

What happens after installing the RHS catchment area next to Eric's house?

1. Eric just finished connecting the RCS to his existing RHS using the manual. He turns on the RCS with a push of a button. He's a little tired from setting it up.
2. The RCS shows with an indicator light that it is switched on. Thanks to the light, Eric knows that the RCS is working.
3. The RCS has a Catchment logic that activates the system when it rains. Eric does not have to continuously monitor that the system is working.
4. Eric goes back inside and continues with his daily life.
5. Slowly it starts to rain, Eric looks outside from his Tiny House and sees that the RCS is already open and collecting the rainwater. It works and that makes him happy.
6. For fun, Eric keeps watching until the rain stops. He sees that the system slowly closes until it is neatly and tightly packed.
7. In the next rain shower, Eric sees that a leaf has blown into the system. That doesn't immediately have major consequences, but he does get it out so that the system continues to work properly.
8. A month later Eric would like to mow the grass and also be able to access it under the system. He forgot to turn off the RCS.
9. The prediction data says that it will rain in 5 minutes. The system slowly rolls out, exactly when Eric is under it. He is startled and quickly push the stop button to prevent a dangerous situation. He is relieved that he was able to make this mistake without anything dramatic happening.

10. A week later Eric hears on the radio that bad weather is on its way and that code orange and maybe even code red are issued for Drenthe, he is not worried. The RCS is designed in such a way that it automatically adapts to the weather conditions. He has read about this in the manual. In very stormy weather, the system will not unfold. This is very convenient for Eric. Even if he or Mara are not at home, nothing can happen that affects the functioning of the RCS.
11. This is good for Eric to know, but he will certainly test whether the RCS works safely with the first weather warnings. Despite Eric operating the buttons himself and try to turn on the RCS, nothing happens. Everything in the manual is also correct in this area.
12. The life of Eric and Mara has become even more sustainable with the RCS. Never again will any stench in their Tiny House be caused by the water. They can use the collected and clean water for all purposes.

5.3 Functional Decomposition

In this section the functional decomposition will be fully done with the help of the level approach (see 3.3.1). In this project there are 3 levels that will be shown. The first level is level 0, this is a overview of the total system with one of the blocks as the RCS. Level 1 is a overview of the main functions and their relations of the RCS. The last level all specific functions will be fully shown in 3 different Figures.

5.3.1 Level 0: System overview

In Figure 40 an overview is given of the full system. The overview is made with black boxes and a stick Figure that represents the user. Stating all different connecting systems plus the user. As can be seen in this Figure, there are 4 different black boxes and the user. The most left box is the Rainwater Harvest system, this is for instance the storage and filters that still needs to be connect to the RCS. The middle function is the RCS and is a subsystem of the total Rainwater Harvest System. This box is called the RCS. The RCS collects the rainwater and give the Rainwater Harvest System this collected water. In addition this system can be turned off and on always by the user and the user will be able to know if the RCS is turned on. Furthermore, the subsystem needs info from a Precipitation prediction source, so it request data about if it is raining at the moment and if it is going to rain in the near future (15 minutes). In return this source will give this raw data back to the subsystem. The last box is the Weather warning. The function sends data when the KNMI says that there is code yellow/orange/red incoming [15] .

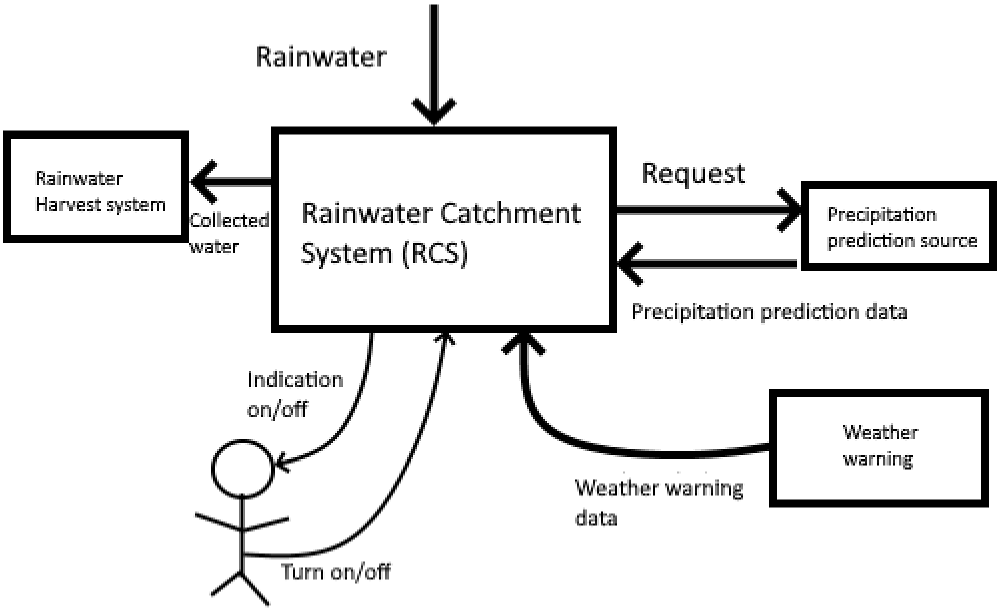


Figure 39 System overview diagram level 0

5.3.2 Level 1: The RCS function description

Zooming in on the RCS, multiple new black boxes are shown, this can be seen in Figure 41. First at the left is the Collector. This system collects the rainwater, outputs the collected water and gets the information open or close. Also, it send out the collector status to the Catchment control. The Catchment controls gets this status, process it and send the Catchment status to Catchment logic. Furthermore it receives the open/close request, process this data and send open or close to the Collector. The last box is the Catchment logic. This function request data and gets the Precipitation prediction data. In addition, it gets weather warning data and the status of the Catchment. Furthermore, it gets from the user information if the system is turned on or off and send back an indication if the system is turned on or off. With all the data it decides to request that the system should be open or close.

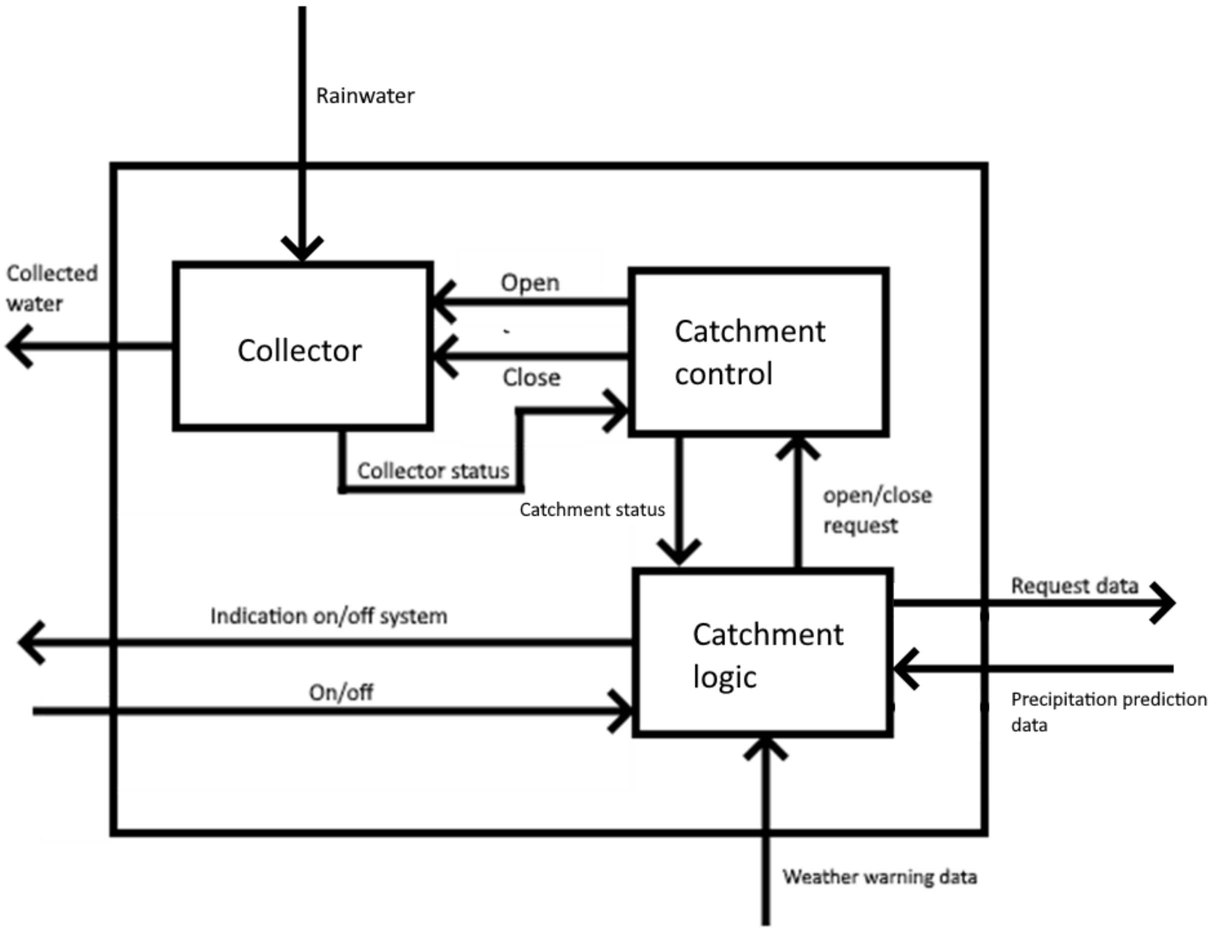


Figure 40 RCS overview diagram level 1

5.3.3 Level 2: The RCS sub-functions description

Collector

Figure 42 shows a decomposition of the Collector function. The Collector mainly consist of the conversion of digital to analogue conversion and back. It converts the open and close information that it gets from the Catchment control and converts it to analogue output. The Rain collector gets this out put and collects the Rainwater, put out the Collected rainwater to the RHS and sends its Roll position information to an inverter that sends the digital data back to the Catchment controller.

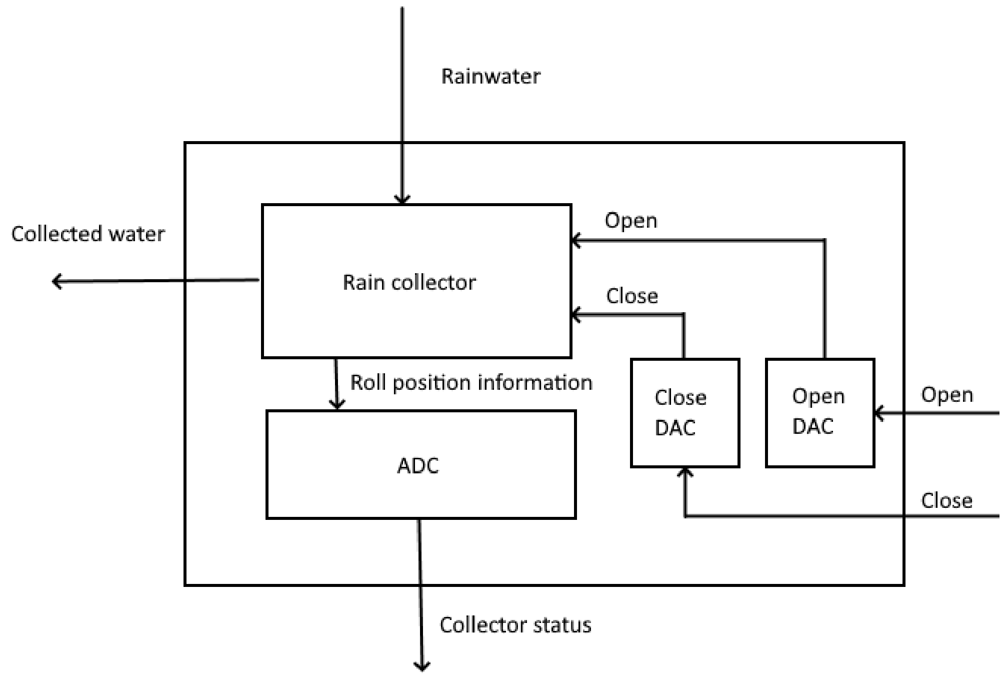


Figure 41 Collector overview diagram level 2

Catchment Control

Figure 43 shows the decomposition of the catchment control. The Catchment Control process the open/ close request and send out the open or close signal. In addition, it generates a time stamp to add to the collector status information that is received from the Collector and this information is send out as Catchment status back to Catchment logic.

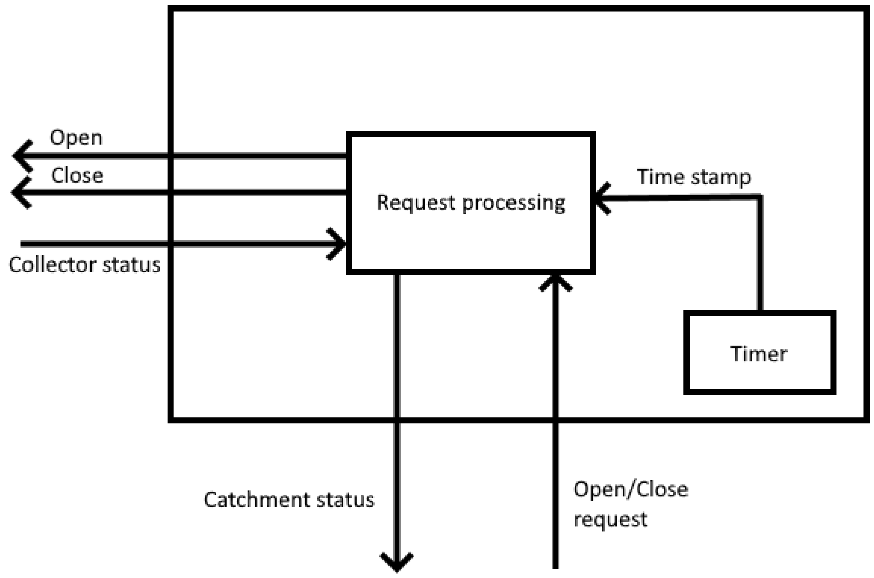


Figure 42 Catchment control overview diagram level 2

Catchment logic

Figure 44 shows the decomposition of the Catchment logic. The Catchment logic can request data from the prediction source and can collect the data. In addition, it gets weather warning data when the weather is getting dangerous. Then the Threshold weather function will say if the data shows enough rain for to request to open the catchment area and that it is safe weather to open the area. However this request should be checked by the Arbitration that checks if the collection area is already open with the Catchment status and checks if the system is turned on by the User. Indicator power gives the information if the system is turned on or off and it send back to the user an indication if the RCS is on or off.

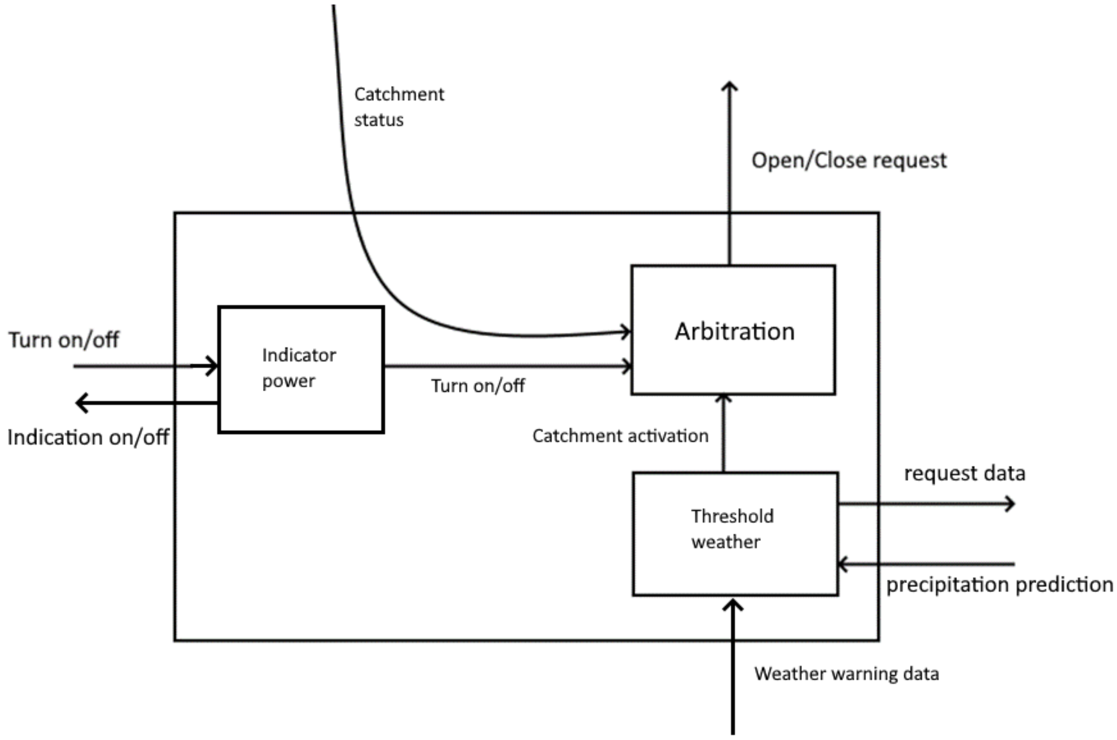


Figure 43 Catchment logic overview diagram level 2

5.4 Functional Requirements and Non-functional Requirements

Preliminary user requirements were stated by the help of the clients. Based on interviews and involvement of the Facebook Group Tiny House Nederland, user scenario and decompensation of functions improved requirements are constructed. The list is ordered in functional and non-functional requirements and following the MoSCoW method requirements. Table 13 and 14 contains the final list of functional and non-functional requirements.

Table 13 Functional requirements

Functional Requirements
Must
The Collector must be already opened when it rains and be open only when it rains.
The Collector must be opened and close in 1 minute.
The RCS must use weather prediction data every 5 minutes to detects when it will rain.
The RCS must be closed when the KNMI says that code orange or red is given in the position the RCS is deployed.
The RCS must detect when the catchment area is rolled open and when it is rolled down.
The RCS must to be able to turn off and on by the user.
The RCS must have an emergency button.
The RCS must indicate the user, if the RCS is on or off.
The Collector must be of a minimal of 60 squared meters.
Should
The RCS should be autonomous.

Table 14 Non-functional requirements

Non-functional Requirements
Must
The Collector must be in a slope of at least 15 degrees.
The RCS must be installable by the user self.
Pole of the RCS must to be lower then 2 meters
The RCS must be low in maintenance.
The RCS must to be easy to use.
The RCS must be easy to set up and tear down.
The Collector must collect rainwater in a clean way.
The RCS must use a wireless networking technology.
Should
The RCS should cost less then 5000 euro.
The RCS should be environmental friendly.
The RCS should be self supporting in energy.

5.4.1 Note on system speed and check frequency

The system should do all its functions in a specific time interval. These will be explained in this section.

First of all, every 5 minutes new data will be collected to see if it is going to rain. This 5 minutes is chosen because the data from Buienradar can change every 5 minutes. Checking for rain with the same frequency will make the chance of missing rainwater as small as possible. In addition, it will cost almost no extra energy to request the data, so it will not be beneficial in terms of energy efficiency to make this frequency larger.

Secondly, it will take approximately 1 minute to open up the sail and 1 minute to close the sail. The speed will be around 13 cm per second. Any slower makes the system safer but the chance to miss rain will be higher.

Chapter 6 - Realization

The focus of this phase is the realization of the prototype of the envisioned RCS. With this prototype the functional requirements can be tested in the form of a proof of concept. First different sub-systems will be identified and what functions it has. Furthermore, the separate subsystems are realized, integrated and afterwards evaluated based on the functional requirements made in the previous phase (section 5.4). In the realization part, the component list can be found so that the prototype can be replicated by others.

6.1 Identifying the different sub-systems

By using the three subsystems stated in 5.3 to make a clear overview, a realization can be replicated by other researchers. The functional requirements that are stated in chapter 5.4 should be paired with the different subsystems to meet all of these requirements and to clarify the realization phase. These functions will be transferred to physical, electrical components. These components can then be integrated and a prototype can be built. The different functions will be built in the physical domain and the electrical domain and for that reason is it handy to make a clear difference between those two. The subsystems can be found in the Table 15 below, including the functions.

Table 15 Subsystem with their domain and functions.

Domain	Sub-system	Functions
Electrical	Catchment controller	The Collector must be already opened when it rains and be open only when it rains. The Collector must be opened and close in 1 minute.
Electrical	Catchment Logic	The RCS must use weather prediction data every 5 minutes to detects when it will rain. The RCS must be closed when the KNMI says that code orange or red is given in the position the RCS is deployed. The RCS must to be able to turn off and on by the user. The RCS must indicate the user, if the RCS is on or off. The RCS must have an emergency button. The RCS should be autonomous.
Physical	Collector	The RCS must detect when the catchment area is rolled open and when it is rolled down. The Collector must be of a minimal of 60 squared meters.

Some additional functional requirements were added due to conversations with stakeholders and discoveries during the development of the prototype and evaluation. These are listed below:

- RCS must indicate to the user if the RCS is on or off.
- The RCS must be closed when the KNMI says that code orange or red is given.
- The RCS must have an emergency stop button.

However these were not realized in the prototype.

6.2 Realization of sub-systems

At the start of realizing the prototype of the RCS different sub systems are identified. Each different system was built first separately. In this section the different systems will be explained and displayed with photos of the prototype. This prototype is made to test if the general idea will work and to show the user an impression of the RCS.

6.2.1 Catchment controller

The catchment controller should be able to control the Catchment area and deal with the information it gets from the sensors of the Collector function and the Catchment logic subsystem. This can be seen in section 5.2.

The Catchment controller is made out of a Raspberry Pi 4. This is a micro controller that can do all the tasks this subsystem should be able to do. The Raspberry Pi is energy and cost efficient and very easy to work with. In addition, the Raspberry Pi has a large following with different forums and extensive support. If a problem occurs, a quick Google search can help you out very easily. Furthermore, the Raspberry Pi has input and output pins; these pins can control different sensors and actuators. The reason why an Arduino is not chosen is because it does not support onboard connection to the internet.

6.2.2 Catchment logic

The Catchment logic should be something that is able to get data from a prediction source on the internet and be able to send out signals to control the sensors and actuator. Python is chosen to be used. It is a well known programming language that is again very well supported on the internet. In addition, Python can be easily be uploaded to a Raspberry Pi. The code will be locally computed to make an easy and quick prototype to test the functionality of the RCS. Furthermore, it is more reliable and robust because the system will be operated independently. The code in Python will make the RCS fully autonomous. The code can be found in Appendix C. The code is made up of different functions. First, it requests data from the API from Buienradar. The weather prediction source that will be used is the API from Buienradar [50]. The API provides precipitation prediction for the next two hours. This API has a small interval in time. It is 5 minutes [46]. This gives a good prediction if it rains at the moment or not. Also, this API can be changed for different location because it is coordinated based.

The raw Buienradar data consists of strings. An example can be seen in Figure 45. These strings are changed into integers and then put in an array. Each element in the array will be cleaned so that the data is in a usable integer form. The data will be analyzed and checked whether the Collector should be opened or closed or it should do nothing. This data will be sent to the actuator that opens the system or closes it. This actuator will open up or close down the system until a sensor senses that the end has been reached. The code will run itself every minute and refresh its data every minute so no rainwater will be wasted. Every drop of rainwater should be caught due to the fact that the area should be as small as possible.

```
b'000|15:55\r\n000|16:00\r\n000|16:05\r\n000|16:10\r\n000|16:15\r\n000|16:20\r\n000|16
```

Figure 44 Raw data String Buienradar API

6.2.3 Collector

The Collector is the surface that catches the rainwater (Rainwater collector, section 5.3.3), the actuator (DAC, section 5.3.3), the sensors (ADC, section 5.3.3) and the system that opens and closes the surface that catches the rainwater (Rainwater collector, section 5.3.3).

The surface that catches the rain is part of the rainwater collector. In the prototype it is the curtain. This curtain is flexible and already have a system inside that makes it easy to open up and close down.

The rest of the rain collector will be done with pulleys and ropes. That can be found in the local hardware store.

The actuator is a servo that opens and closes the rainwater collector. The servo can control the speed of the rainwater collector so that it will be able to open and closed in 1 minute.

The sensor needs to sense when the rainwater collector is open or closed. This sensing should be very reliable to prevent the actuator from over tightening or over stretching the rope. This is done with limit switches. These switches were chosen because they are easy to use and perform the required function.

6.3 Integration

Now the different subsystems will be integrated in to a prototype. The prototype will be additionally used to show the mechanism and to test the code. However, the prototype is scaled down by a factor 7.8 and only one sail is made. The factor is chosen because of the available materials and made in a practical size. Only one sail is made because this shows the functionality enough of the product. The prototype is a proof of concept in a scaled down version. In addition, the prototype is not waterproof, because experiments that would require waterproof system such as testing the water quality required parts that were not easily accessible, such as a tarp (too expensive) waterproofing switches, and waterproof casing for the Raspberry Pi.

6.3.1 Prototype

In this section, first all the component that are used in the prototype and a clear overview will be given. Finally, all different subsystems will be explained.

Component list Catchment control

- 2x limit switch
- 2x 10k Ohms resistor
- 1x continuous rotation servo
- Bread board
- Raspberry Pi 4B
- Wires
- Dynamic Pulley
- Rope
- Static Pulley
- Curtain
- PVC piping

- Wood (60*100*0.3 cm)
- Nails
- 3D prints
- Piece of plastic for trigger mechanism

Prototype overview

In the Figure 46 below a overview is given of the prototype. In addition, the different subsystems can be seen. The green triangle is the Collector system and the red square the Catchment control. However, the last sub system can not be seen in the picture. This is the Catchment logic and this can be found inside the Raspberry Pi in code language thus not in Figure 46. In the rest of this section, the different subsystems will be explained.

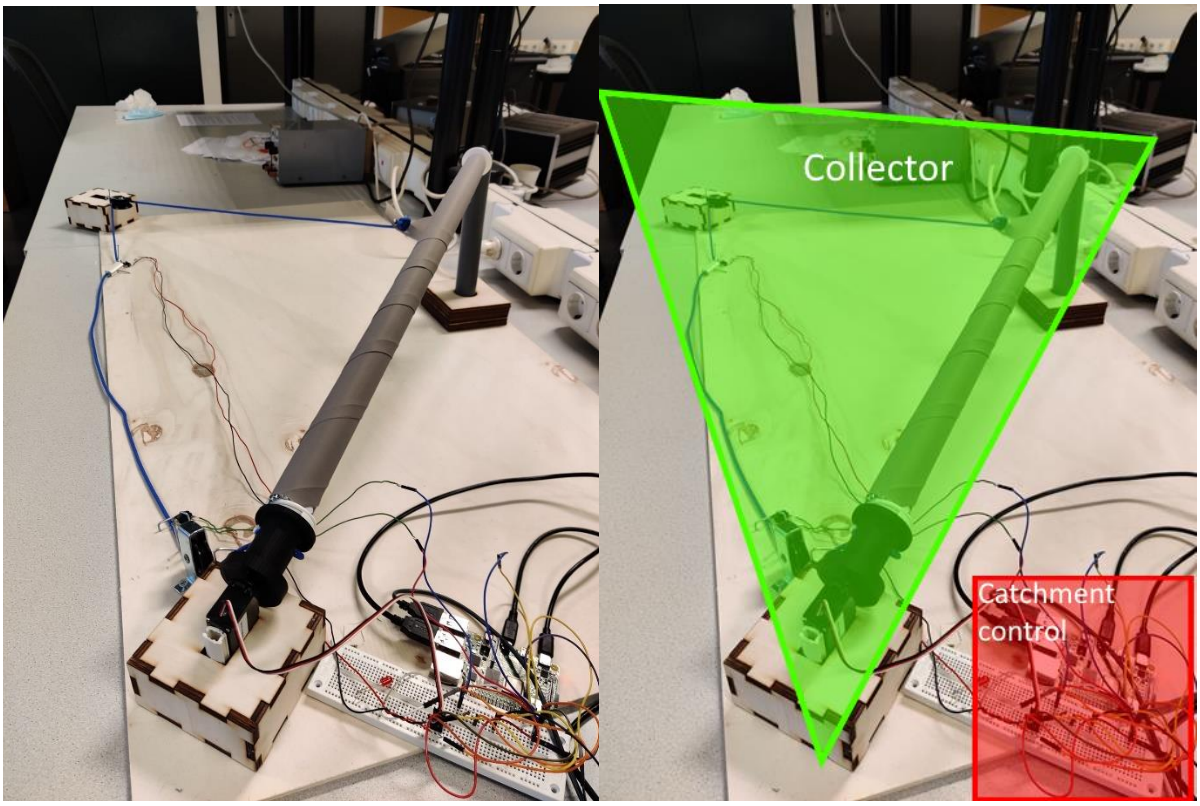


Figure 45 Overview of the prototype

Catchment control

In the prototype, the Catchment control is represented in the form of a Raspberry Pi. In Figure 47 can be seen how the Raspberry Pi is connected to the other sub-systems.
The limit switches will relay if the catchment collector is open or closed. The servo is a continuous servo. This servo is chosen in this prototype because it has a gearbox inside and will have enough torque to be able to rotate the tube and curtain forming the water Collector. The limit switches are very similar to those shown in Figure 47; the switches that are used do not have a PCB board with them and are normal limit switches. The switches can be seen in Figure 49.

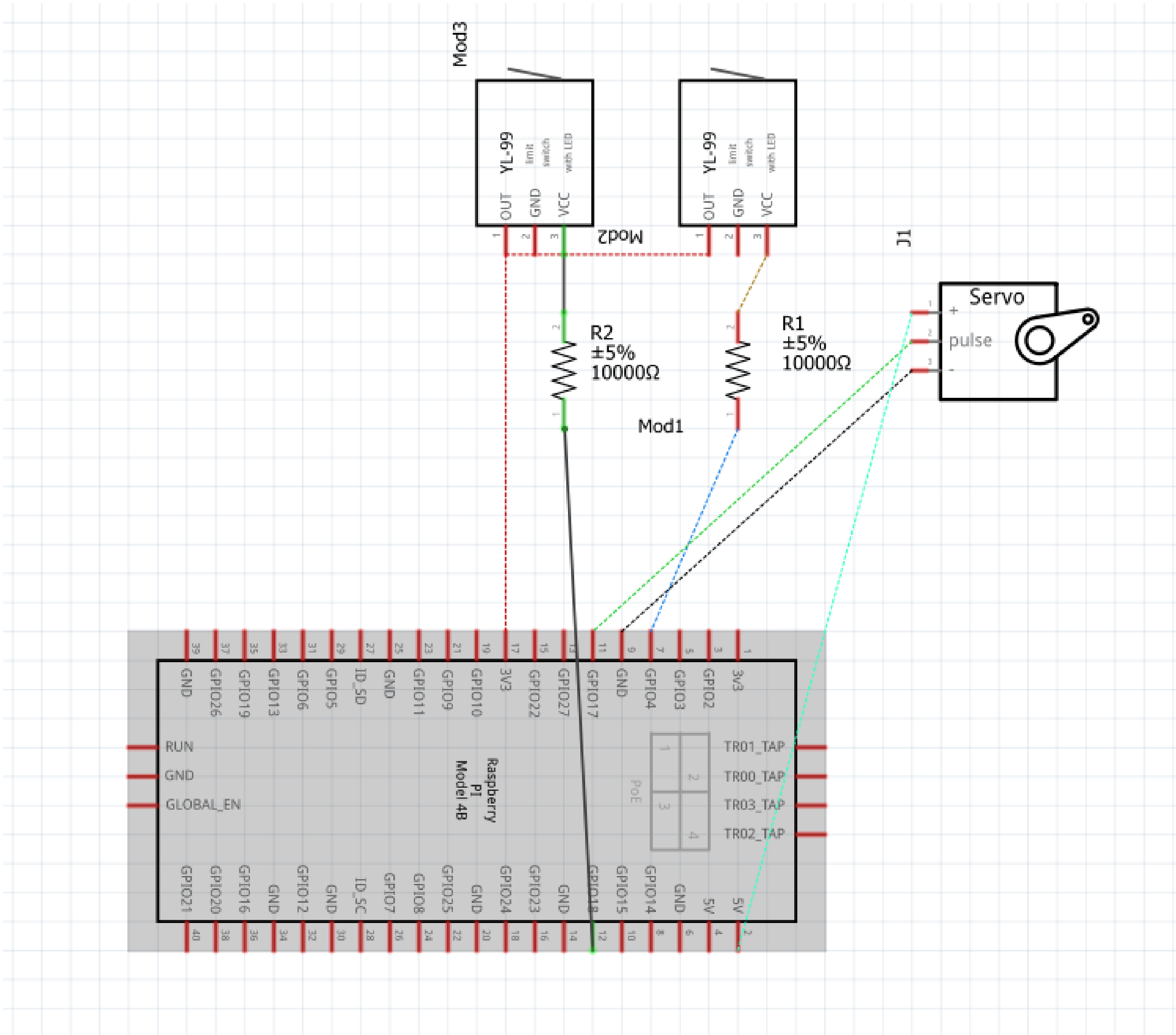
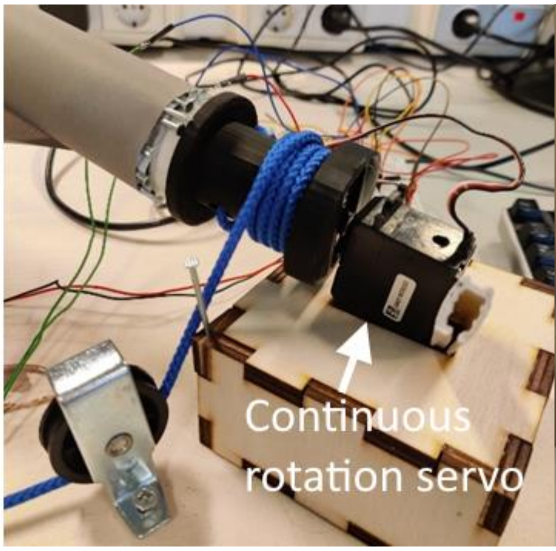


Figure 46 Electrical diagram prototype

In the picture 48,50 below the Raspberry Pi 4B and the continuous rotating servo can be seen.



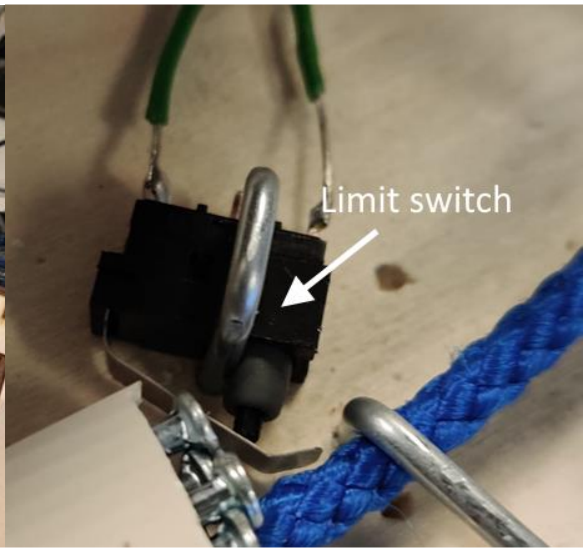


Figure 47 Prototype continuous rotation servo *Figure 48 limit switch*

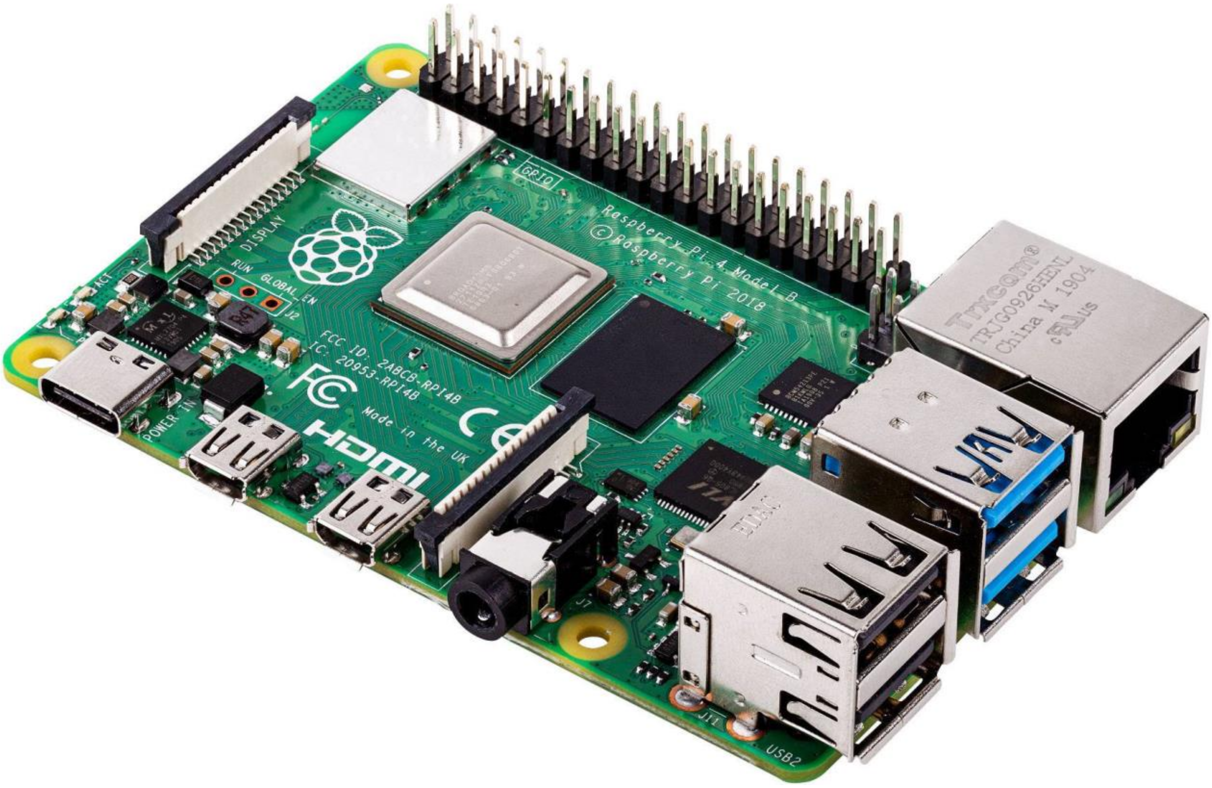


Figure 49 Raspberry Pi 4B

Source: adapted from [51]

Catchment logic

In the prototype, the Catchment logic will be the same as in the RCS. The programming language is Python. The code can be found in Appendix C. There is no code for turning off and on system because this part of the product will not be evaluated in this project. So for that reason it was not made. This is the same with the color codes (heavy storms) by the KNMI. This function will not be evaluated in this project, so it is not made. The reason why it will not be evaluated is because in this stage, the project focusses more on the idea of the product as a way of getting water instead of the safety of the product.

Collector
In the prototype, the Collector is a rollable curtain bought in a local hardware store. This curtain is chosen because it already has the turning mechanism inside. In addition, it is affordable and the material is flexible and rollable. The curtain and the collector as whole can be seen in Figure 51.

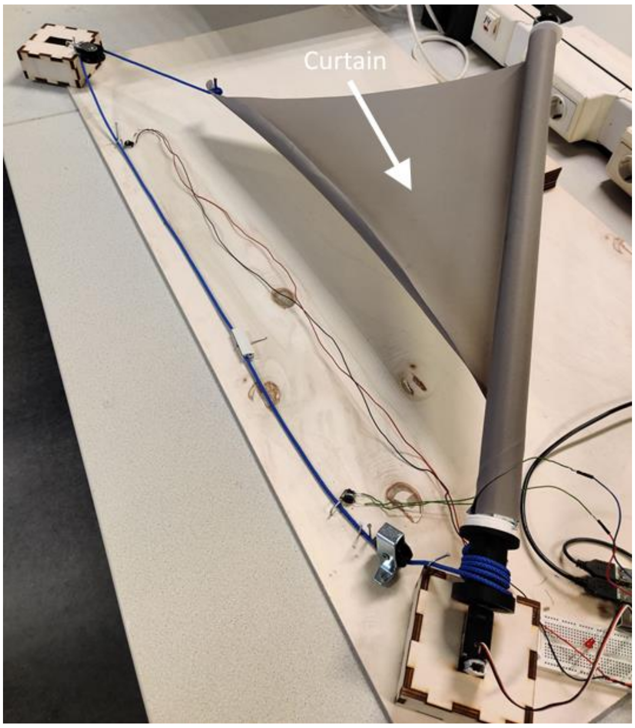


Figure 50 Prototype Collector system

To make sure that the water will flow to the lower corner of the collector (curtain), that corner is made heavier and positioned lower than the other. In the prototype, several nails are used to structure and weigh down one corner. This can be seen in Figure 52. In this Figure the nails or on top of the curtain to make it more visible how this corner is weighted down. In the prototype the nails will be on the back of the curtain.

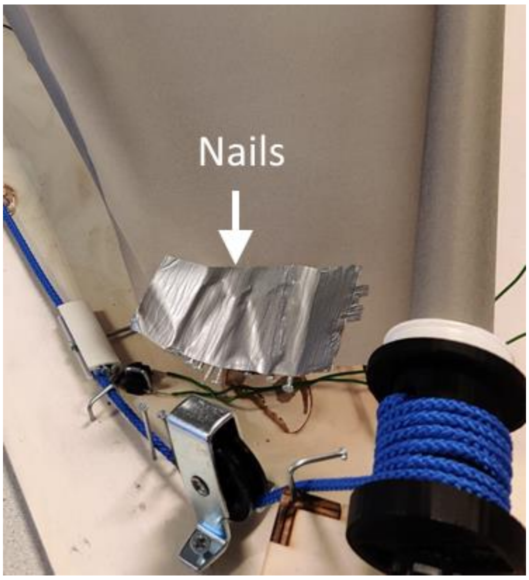


Figure 51 Weighted corner

The rope in the prototype tensions the rainwater collector and helps open it up. The servo unrolls the rope so that the edge of the collector is drawn to the corner. This corner is positioned with the help of a pulley that can be seen in Figure 53.

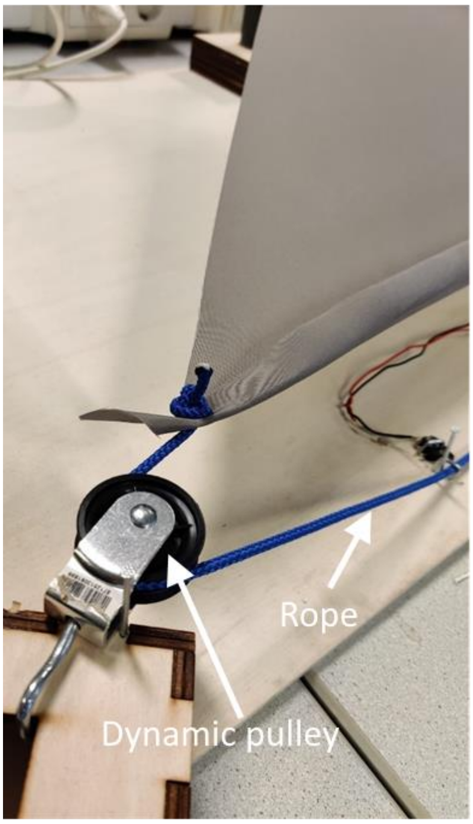


Figure 52 Rope pulley mechanism

The switches are used to track if the rainwater collector is open or closed. To trigger the switches, a piece of plastic is attached to the rope so that when the rainwater collector reaches its end point this piece of plastic triggers the switches. This mechanism can be seen in Figure 54. In the Figure the limit switch is pushed in. Initially, the rope was turning during the rolling of the rainwater collector. This led to unreliable triggering of the switches. To solve this issue, nails were added to keep the plastic in place.

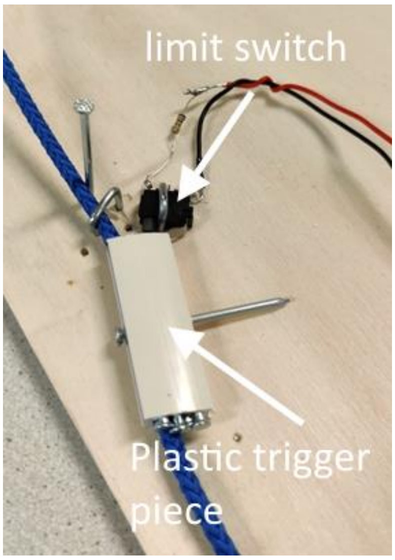


Figure 53 Plastic trigger mechanism

3D printed parts

The prototype got two different 3D printed parts, an overview can be seen in Figure 55. These parts connects the curtain to the rest of the system. First the top part of the curtain pole will be discussed. Secondly, the bottom of the curtain pole will be discussed.

Figure 54 Overview 3D printed parts

The curtain pole rests on top of a support. First the idea was that this was connected by rope as can be seen in Figure 56 below. However with such system the rope should be tightened extremely to make the pole hang straight. To solve this issue the pole with the curtain rest directly on the support as can be seen in Figure 57. The SOLIDWORKS design of this part can be seen in Figure 58, 59.

Figure 55 Final Top 3D printed part

Figure 56 Final idea Top 3D printed part

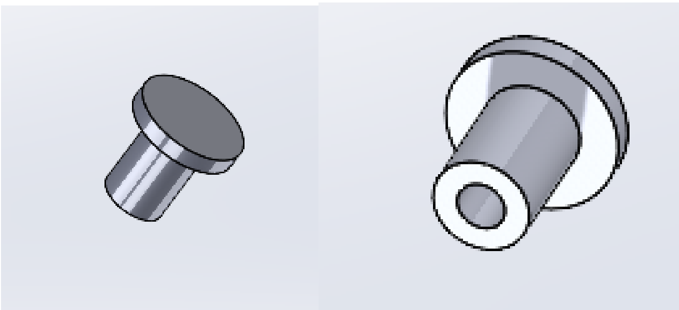


Figure 57 SOLIDWORKS Top 3D printed part

The bottom part of the curtain pole should function as a transformator from the servo to the pole and it should tighten the rope in such way that the Collector surface is tight. The 3D part that is made can be seen in Figure 59 and Figure 60 shows the SOLIDWORK part. In this part, a hole is drilled so that the ropen can be connected to the 3D part.

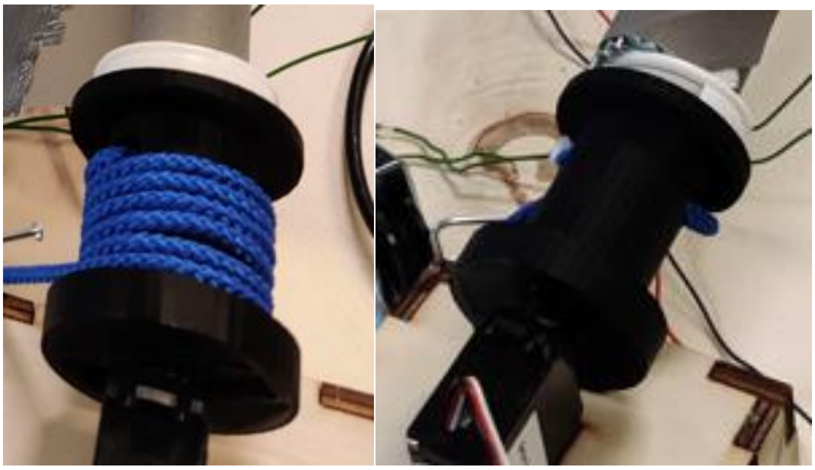


Figure 58 Bottom 3D part rolled up and down

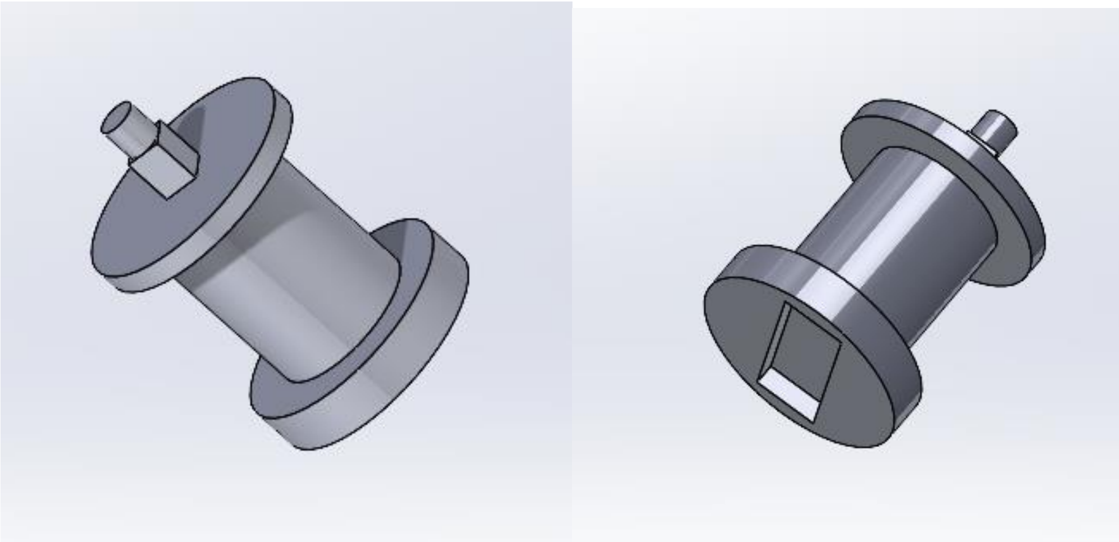


Figure 59 SOLIDWORKS Bottom 3D printed part

6.4 Evaluation of prototype

The evaluation of the prototype will be done with the functional requirements Table that is developed in the specification phase (Chapter 5). Table 16 shows if each requirement is met.

Table 16 Functional Requirements Realization

Functional Requirements	
Must	**Requirement met?**
The Collector must be already opened when it rains and be open only when it rains.	YES
The Collector must be opened and close in 1 minute.	YES
The RCS must use weather prediction data every 5 minutes to detects when it will rain.	YES
The RCS must be closed when the KNMI says that code orange or red is given in the position the RCS is deployed.	NO
The RCS must detect when the catchment area is rolled open and when it is rolled down.	YES
The RCS must to be able to turn off and on by the user.	NO
The RCS must have an emergency button.	NO
The RCS must indicate the user, if the RCS is on or off.	NO
The Collector must be of a minimal of 60 squared meters.	NO
Should	
The RCS should be autonomous.	YES

Table 16 shows that some are requirement is met. However the requirements that were planned before are almost all met. The only requirement that is not met is that the prototype is not really easy to set up and tear down. In the prototype, this requirement could not be met because the right materials were not available to make a modular version. Furthermore, there is still a lot of room for improvement for all the functional requirements that are not met. This improvements should be done to be able to test the concept even further and see if it works on a 1:1 scale.

6.2.1 Suggested changes

During the realization of the prototype, new insights developed, for ways in which the prototype should by changed. Implementing these changes will improve the prototype and a good functional 1:1 scale prototype can be made.

First, one of the functional requirements was that the user should always be able to turn off the system. In the prototype, this not really realized. Now the user should stop running the code. This could be improved by adding a separate power switch or button. This will be more intuitive for the user. During the build process, sometimes the prototype did get stuck or over tightened the rope. A quick stop by an emergency button would be a good addition and would met the another functional requirement.

Secondly, the requirement that the systems should be able to detect whether the curtain is open or closed is realized in the prototype with limit switches nailed down in the board. This will not be possible in a 1:1 scaled RCS prototype and should be made differently. This can be done for instance by attaching the switch to the pulleys, so that it will always be in the same position relative to the rope as can be seen in Figure 62. The plastic piece that triggers the limit switches should also be made differently. It should be something that attaches to the rope and that can trigger the switch in 360 degrees around the perimeter of the rope. This can be seen in Figure 61. Left is the situation now and right will be the upgraded version.

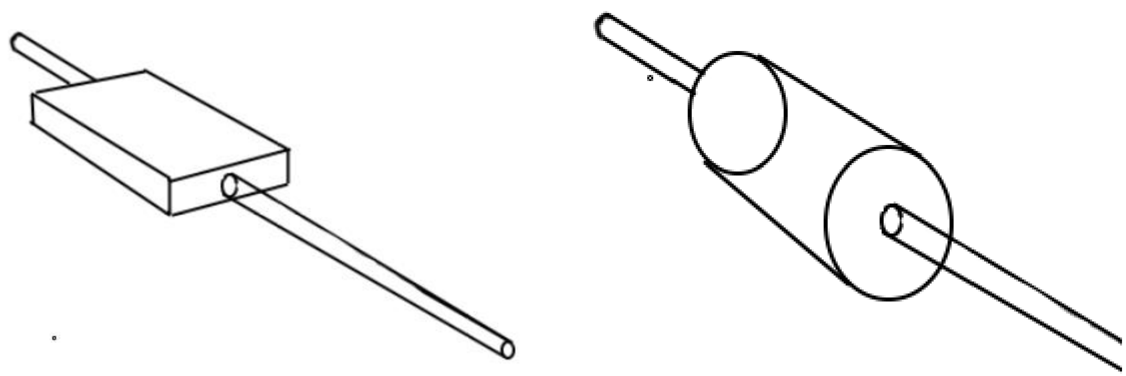


Figure 60 plastic trigger plastic old-new

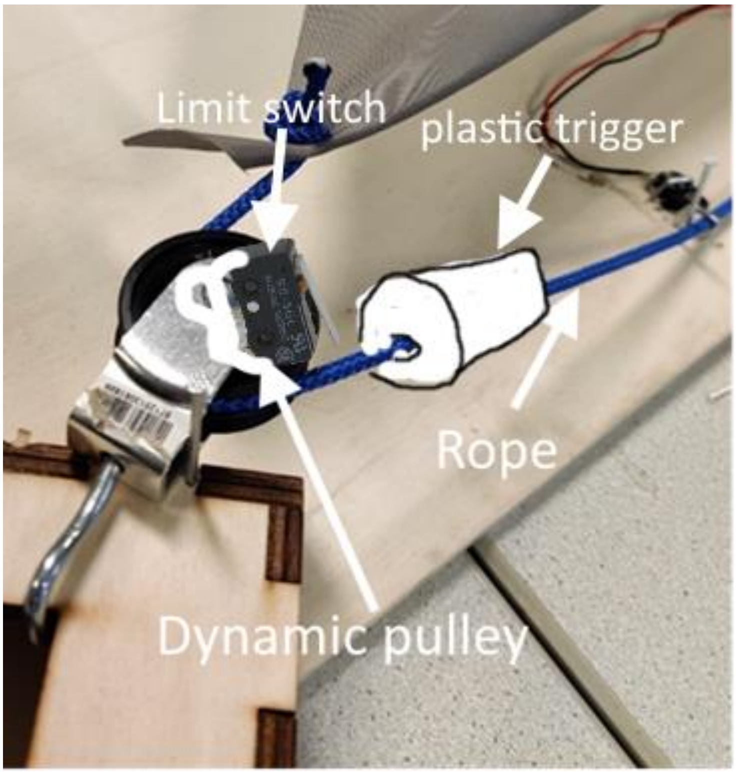


Figure 61 New place of the limit switch

Another improvement could be in the winding mechanism seen in Figure 63. The pulley that is screwed down into the wooden board will not be the same as in the real RCS. The rope should be better aligned so that this pulley is not needed. The Bottom 3D printed part should also be improved. This piece of plastic is not consistent in winding up the rope. Sometimes the ropes rolls up on itself as can be seen in the Figure, causing the curtain to be tightened more then when the rope does not rolls up on it self. This problem can be solved by making big grooves in this piece of plastic so that the rope will lead into this grooves and automatically be ordered nicely on this piece of plastic.

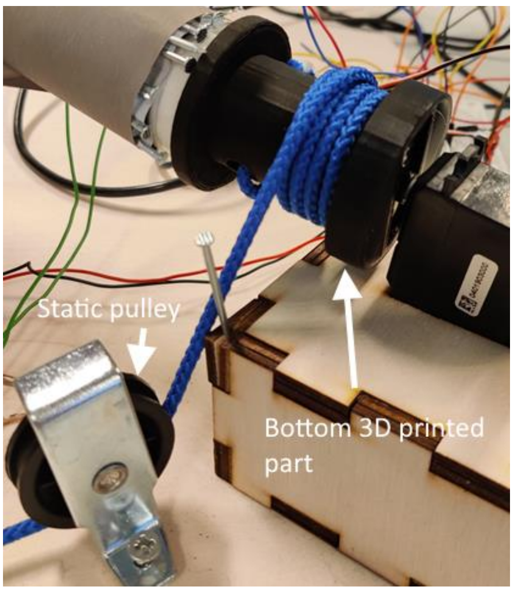


Figure 62 the winding situation

Chapter 7 – User evaluation

The evaluation phase of the design process will give in-depth information about the RCS that is realized. This is done by evaluating the RCS in different ways. The first method is by asking the main stakeholders' opinion. This is done via a questionnaire. Finally, a conclusion will be given.

7.1 Evaluation setup

To evaluate the RCS, a questionnaire was used. This questionnaire was sent to Tiny House owners . By answering the questions, the Tiny House owners evaluate the prototype and the design of the RCS. To give the Tiny House owners a clear idea of the RCS, a video was made. In this video, the RCS and its functions are visualized. The video that was made is in total 2 minutes and the questions to answer will take the participant also 2 minutes. The data can not be tracked back to a specific person and the analyzed data will be used in this chapter. 11 persons participated in this evaluation. The rest of the data will be deleted. The participant needed to give consent, as can be seen in Appendix B in the first question.

The questionnaire can be found in Appendix B. The questions give information about the advantages and disadvantages of the RCS. The questionnaire is made with Google Forms [52]. In the questionnaire, the Tiny House owner were asked if they live in a Tiny House and with how many people. With this question, specific groups within the stakeholders can be defined. One of the groups is the "person living in a Tiny House with one other person". This group is most interesting because this group could include future costumers.

7.2 User evaluation results

In this section, all the results of the survey will be given. The conclusion of these results were stated in chapter 7.3. The Dutch version of all data can be found in Appendix B.

As can be seen in Figure 64 below, the participants consist mainly of Tiny House owners or people that will later live (still in building/designing stage) in a Tiny House in the near future.

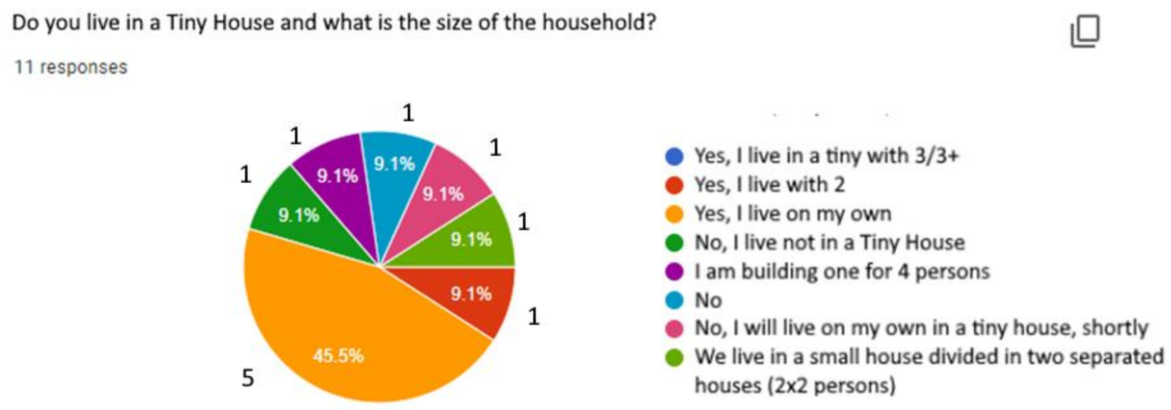


Figure 63 Diagram Tiny house and size household

Some of the participants already have a RHS or want to built one. This can be seen in Figure 65. However, the largest portion of the participants do not have a RHS.

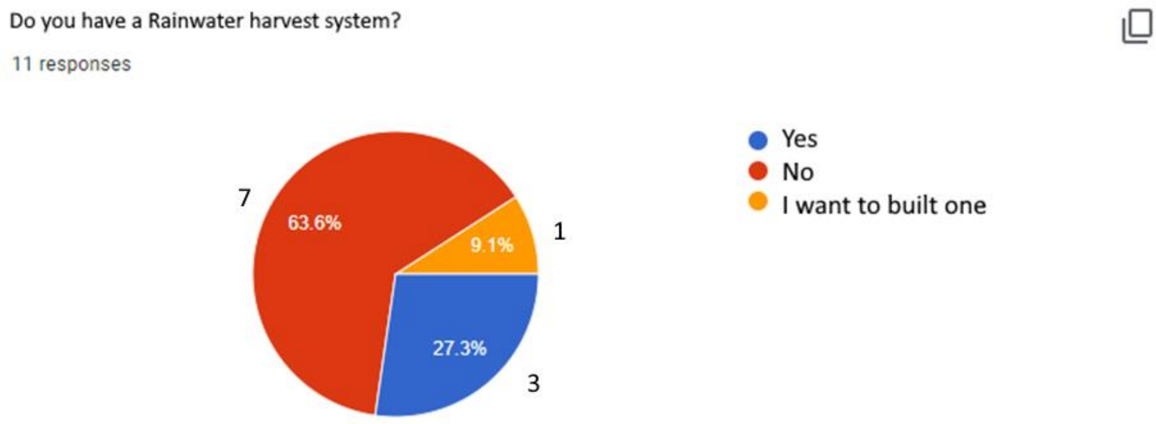


Figure 64 Diagram owning RHS

In general, the impression of the RCS is neutral to positive. However, there are also some negative impressions. This can be seen in Figure 66. The three persons that had a negative submission. Gave as reason that water is to cheap for such system, it is too big and the prototype does not show how the water will be connected to the Tiny House.

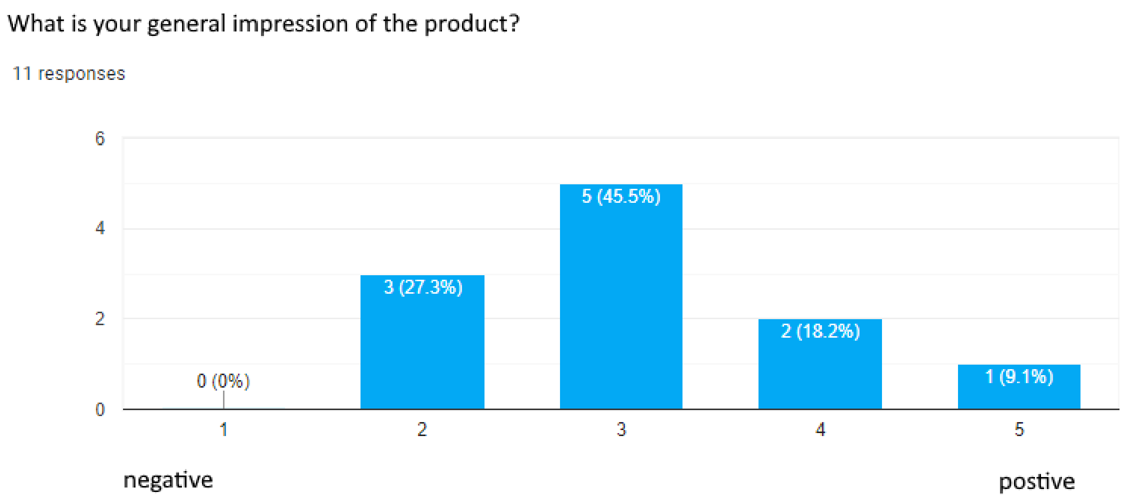


Figure 65 Diagram general impression RCS

The most appealing aspect of the RCS is the that it collects water in a sustainable way, via rainwater. In addition, participants like the fact that they can be fully off-grid with this RCS. The portability of the RCS is not specifically appealing, as can be seen in Figure 67.

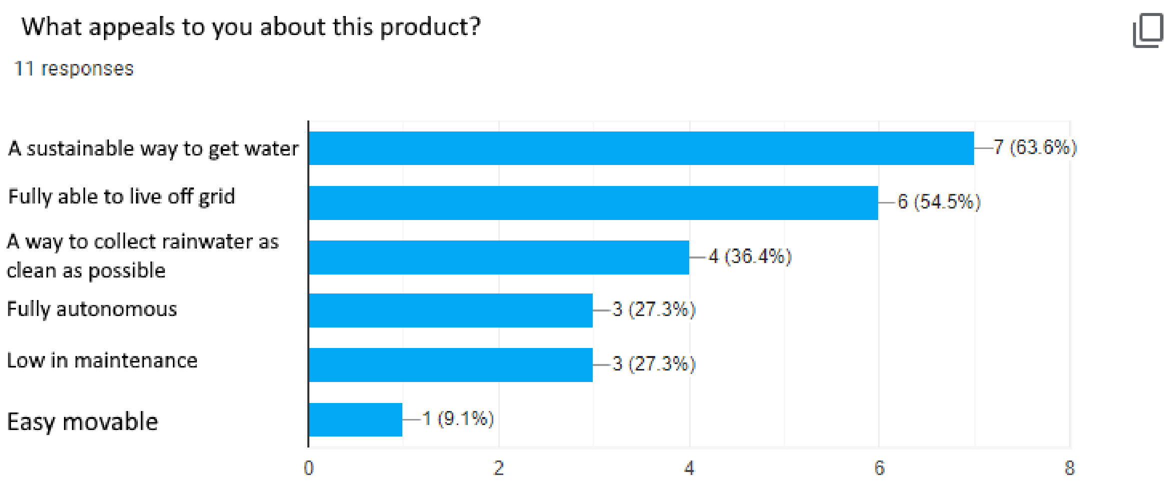


Figure 66 Diagram appealing aspects RCS

The following two Figures 68, 69 reveal significant insights. People do not have the space for such a large system; only one participant would have the space for the RCS that is 60 squared meters.

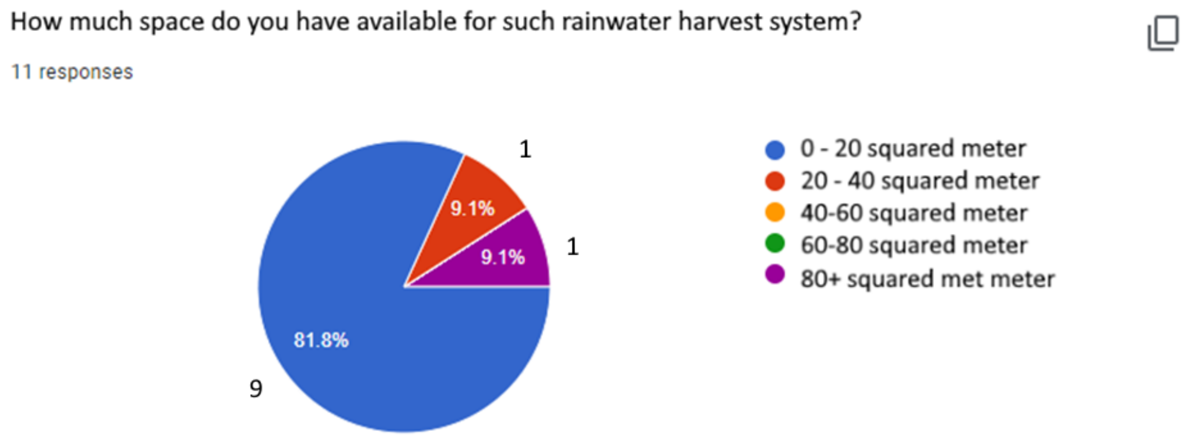


Figure 67 Diagram space availability

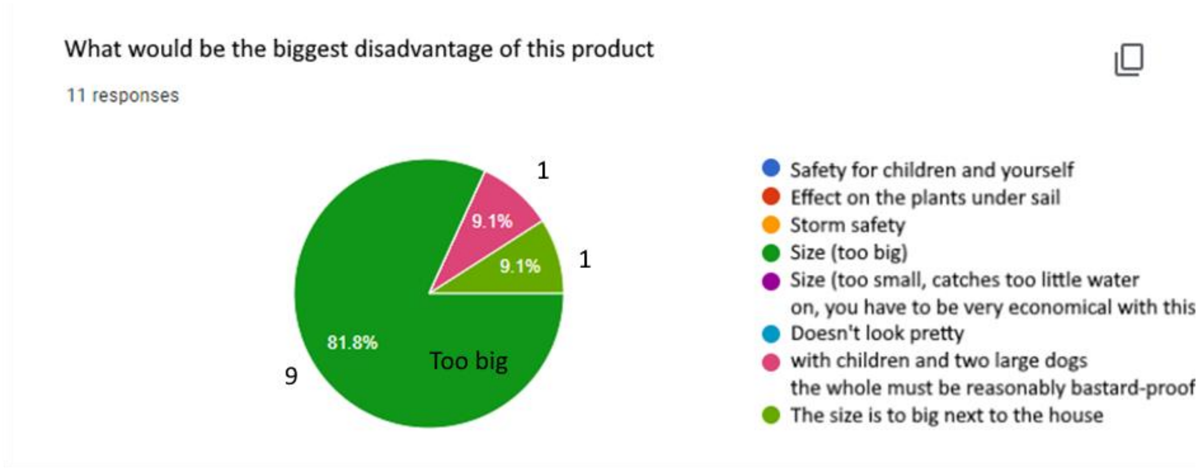


Figure 68 Diagram disadvantages RCS

The participants are generally agree that the RCS should be made out of sustainable materials. The biggest portion of the pool of participants agrees to this, as can be seen in Figure 70 below.

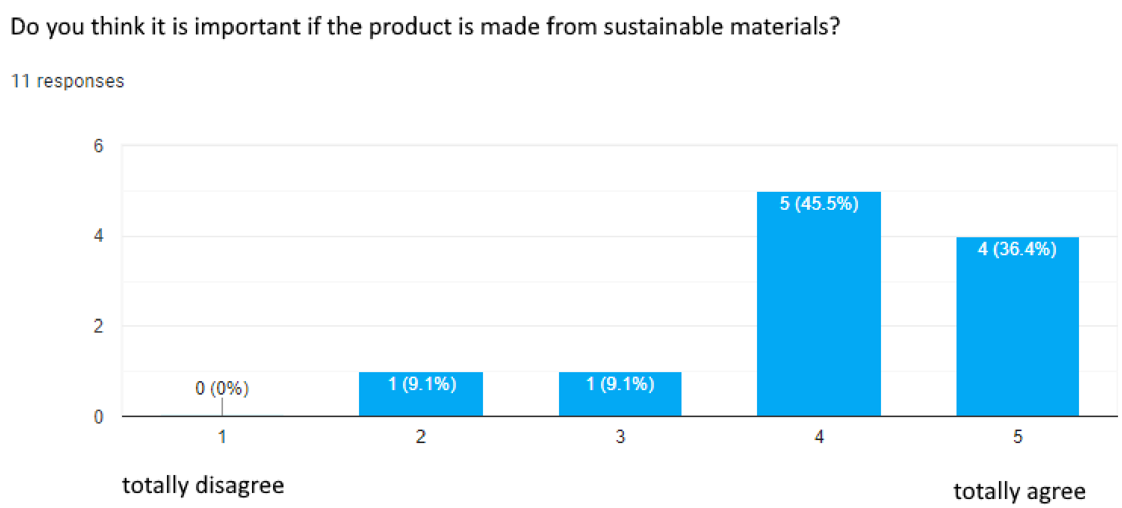


Figure 69 Diagram need of sustainability of the RCS

Participants were also asked to define what they miss in the RCS. The most common response was the aesthetics of the RCS. Furthermore, the RCS uses energy and this is also not ideal of the participants. This all can be seen in Figure 71 below.

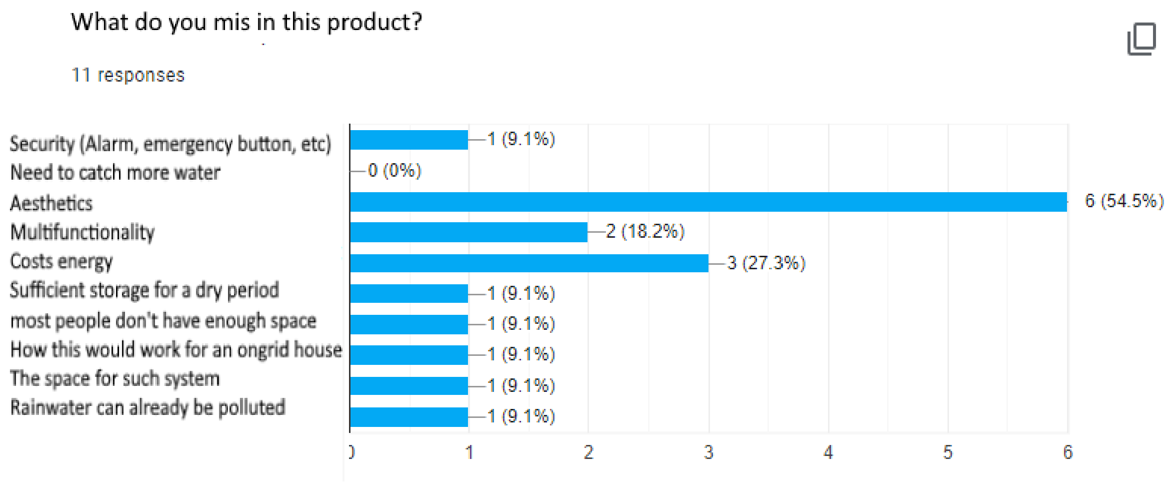


Figure 70 Diagram missing aspects of RCS

The upcoming three Figures 72, 73 and 74, shows that when the price of water increases, the participants are willing to pay more for the RCS. However, the RCS should never be more then 3000 euros.

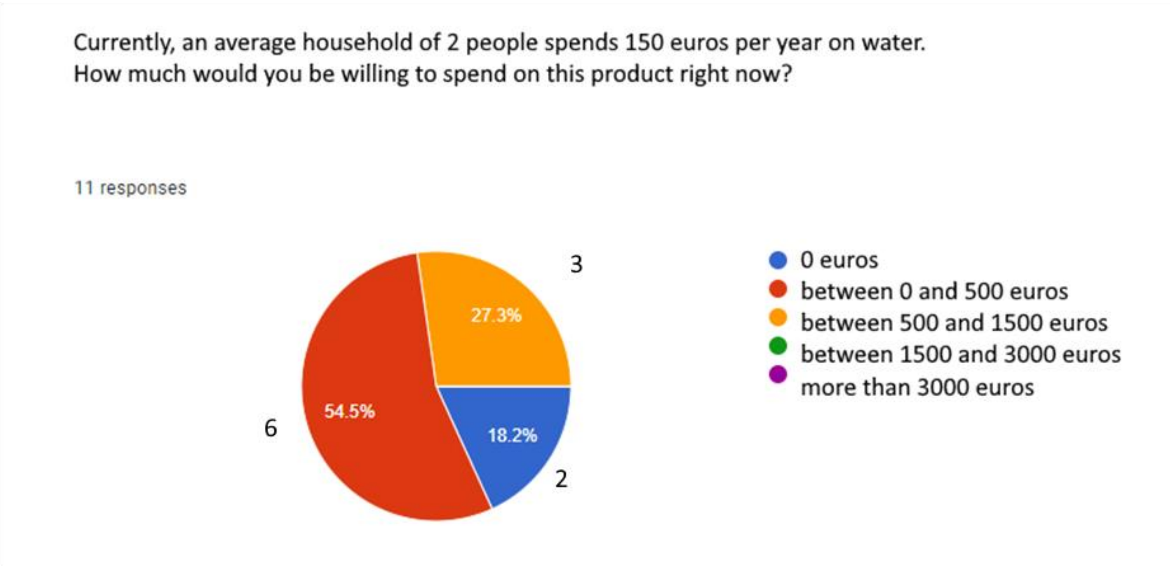


Figure 71 Diagram money willing to spend RCS (current water price)

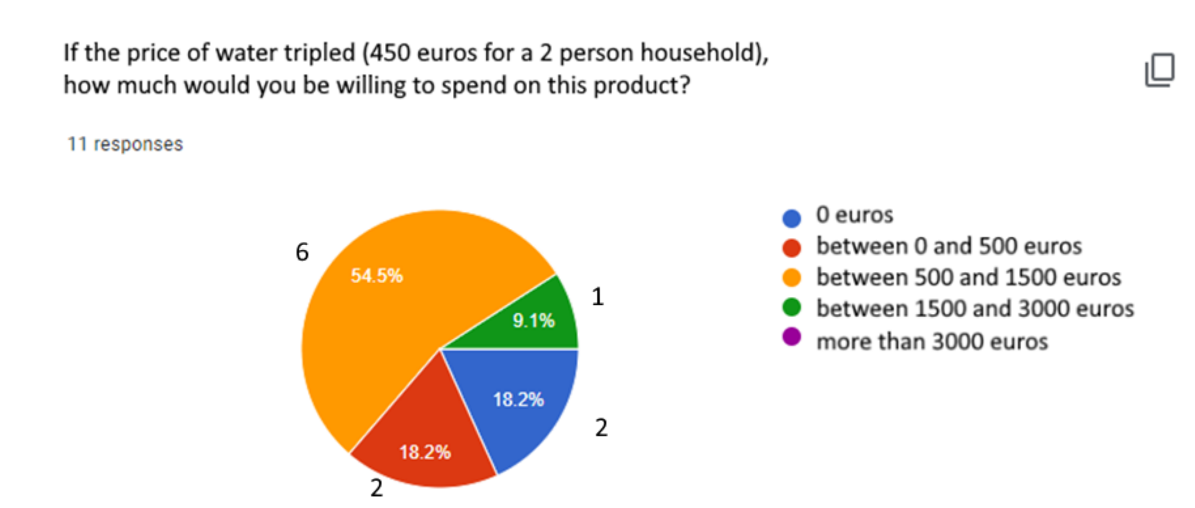


Figure 72 Diagram money willing to spend on RCS (tripled water price)

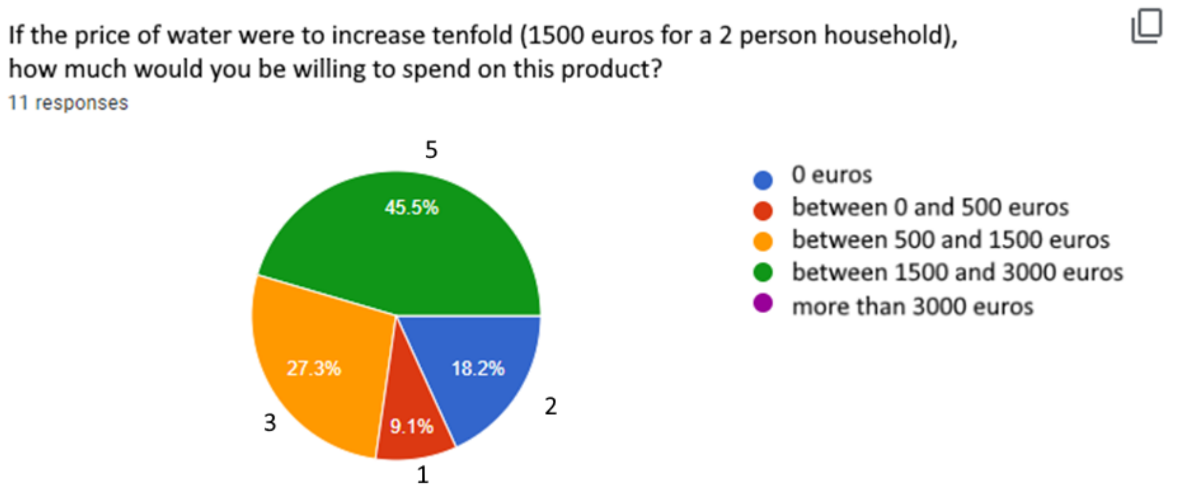


Figure 73 Diagram money willing to spend on RCS (tenfold water price)

7.3 User evaluation conclusion

Concluding the evaluation phase of the project, the most commented feedback on the RCS was that it is too big. The size should shrink to make this RCS useful for the majority of the Tiny House owners surveyed. No participant talked about using less water. Maybe they did not think about this. However, the prototype is already based on 2 persons that are reducing water usage. They do use a compost toilet, do not have a washing machine, use special showerhead and do not water their garden. So reducing in water usage will be very difficult and is for that reason this topic is not being questioned. In another point of evaluation is that while water is cheap, the participants do not want to spend much money on the RCS. However, as water becomes more expensive, the participants are willing to spend more on the RCS. This implies that the RCS is interesting to buyers when it begins to save participants money, but it should always be less then 3000 euros. Furthermore, the participant would like to see the RCS be made of sustainable materials and the aesthetics should be improved. Based on these results, a set of recommendations will be made and discussed in Chapter 8. This chapter will be about the future work for the RCS.

Chapter 8 – Discussion and Future work

8.1 Discussion

When revising this graduation project, some shortcomings should be discussed.

First of all, it is assumed that the RCS will collect rainwater in a cleaner way than other products. However, this was never tested. It was assumed that the chance of collecting polluted materials on the catchment area is lowered due to the fact that the catchment area only opens when it rains.

Secondly, a requirement that is stated was that the RCS will be low in maintenance. This is interpreted in a way that the RCS should require less maintenance then existing products. However, such comparison is hard to measure and the total maintenance on the existing product is just estimated.

Thirdly, it is not researched when the cost of living rises (water gets more expensive). What will happen to the need and the interest of the RCS. In the evaluation it is only ask if the participants wants to spent more money on the product. However, it would be more interesting to ask if the participants wants to reduce in water usage or wants to make more space for the product. When the water price rises.

Fourthly, making the prototype in a scaled down version and not waterproof gave not a full insight of the designed concept. It could not be test outside and be seen if the RCS could collect enough water. It would be good to have made a full scaled prototype to be able to test all the requirements that were stated in chapter 5.

Lastly, the evaluation is done with only 11 participants. This is a low number of participants to be able to say anything for the total population. No statistical significance can be made with this survey.

Biased sample: people with Wi-Fi, active on Facebook and within personal network

8.2 Future work

While a lot of progress is made in this graduation project, the RCS is far from realized. A lot needs to be improved before this RCS is marketable. In this chapter, some recommendation for future work will be given.

First of all, one of the requirements of this graduation project was that the RCS should be easy to set up and tear down. This requirement has not been realized yet. Another question was how to make the RCS portable. The concept that was chosen was chosen because it has the option to be easy to set up and tear down. However this could be worked out further and realized in future work.

Secondly, from the evaluation, the participants seemed to value that the RCS will be fully made out of sustainable parts. Again, this was not fully realized but can still be done with the concept that was chosen. It would be interesting to see how sustainable this RCS can be and what exact materials and components should be used.

Thirdly, the participants of the survey also indicated that the aesthetics should be improved, so that it connects more to the Tiny House. It would be nice to see how the RCS can be in such a form that people would be pleased to have the RCS next to their house. In addition, the participants wanted that the RCS should be multifunctional. It could be made in a way that it also functions as a sunshade for instance.

Fourth, the prototype was built and tested indoors. This will not mean that the functions still work outdoors. The RCS should be optimized so that it will work in the Dutch weather and be fully tested for Dutch weather. Further research should still be done to ensure that the RCS is weatherproof.

Fifthly, many of the participants do not have enough space next to their Tiny House. However, some of these participants commented that it would be interesting if this RCS can be used in combination with an RCS placed on the roof. Therefore, another alley of further research could be determining how many square meters are needed in combination with an existing RHS, and whether Tiny House owners would be more interested in a hybrid product.

Finally, the most important thing to test is if the collected rainwater really is cleaner compared to other systems. This should be tested for a long period of time to obtain the best knowledge about the improvement that the RCSs give. In addition, it would be interesting to know what the cleaner rainwater does to the rest of the system and if some filters can be neglected.

Chapter 9 – Conclusion

This graduation project was aimed at developing a Rainwater Catchment System (RCS) that reduces the water contamination for a Tiny House household of 2 persons. In addition, this RCS should be low maintenance, portable and weatherproof in the Netherlands. Research revealed that the minimal horizontal catchment area needs to be 60 squared meters to provide enough water for a Tiny House household of 2 in the Netherlands (approx. 48000 liters a year). This area is the absolute minimum needed to be self-sustaining. The household should be extremely sparing with water usage and the materials that should be used in the RCS should give the best run off coefficient possible.

By using an active RCS that opens of closes depending on the weather, the RCS can be portable and collect water without contaminating it, setting the RCS apart from existing RCS's that are on the market. By only having the rainwater catchment open when it rains, the chance of pollutants collecting on this area will be lower.

After talking to the experts and the main stakeholder group different requirements were created. These requirements should be met to make a functional and well thought-out RCS.

In short the requirements were:

- Easy to setup and tear down
- Easy to use
- Low maintenance
- Fully support in water consumption
- Weatherproof
- Environmental friendly
- Autonomous
- Affordable
- Self supporting in energy

Based on research, expert and stakeholder interviews and a brainstorm session, the new Rainwater Catchment System (RCS) was designed. This RCS will collect rainwater as cleanly as possible, so that there is less filtering needed before the water can be used. The active mechanism is a rollable rainwater catchment area. Furthermore, the RCS is equipped with a micro controller that connects the RCS with Wi-Fi, and this computer makes the RCS fully autonomous. The user will not have much maintenance to this RCS because it is autonomous and because of the roll mechanism.

After evaluation, the RCS seems interesting and promising. Collecting water in a sustainable way is interesting to many people because living fully off grid and is a dream for many of Tiny House owners. However, at the moment the water is not expensive enough for people to commit to the RCS. They do not want to spend much money for it, if they do not get the money back in free water. In addition, the RCS dimensions are too big for the common Tiny House owner in the Netherlands. People do not have the space for it in their garden. Furthermore, almost every participant wants that the RCS to be aesthetically pleasing.

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Appendix A through C

Appendix A list of sources

List of sources for the collage:

Collage one:

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Collage three:

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Collage seven:

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Concept 2:

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Concept 3:

https://zwembadcompleet.nl/intex-easy-set-zwembad-366-x-76cm?gclid=Cj0KCQiA3fiPBhCCARIsAFQ8QzUqjy5NZd1YZpcjAcmjmOQyrsNmEC2K7ifxOrtEKQ4yV_0p1bASkzoaAjewEALw_wcB

https://www.jpl.nasa.gov/edu/learn/project/space-origami-make-your-own-starshade/

Concept 4:

https://www.swimmingpool.eu/en/products/19682-cover-open-aero-from-abriblue-for-swimming-pools-controllable-via-your-smartphone

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Concept 6:

https://www.sail-world.com/photo/304082

Appendix B Questionnaire + Data

Questionnaire:

Regenwater opvangsystem Vragenlijst

Welkom, bedankt voor uw deelname aan deze enquête over een Regenwater opvangsysteem. Hieronder kunt u informatie vinden over de enquête.

Mijn naam is Marnix Riepen. Ik ben een student aan de Universiteit Twente en doe onderzoek voor mijn bachelor afstudeeropdracht van de studie Creative Technology. U kunt mij bereiken tijdens en na het onderzoek door mij te mailen via m.m.j.riepen@student.utwente.nl. Alle vragen behandel ik vertrouwelijk. Mijn toezichthouders zijn: DR. K. Zalewska (k.zalewska-kurek@utwente.nl) en IR. ING. R.G.A. Bults (r.g.a.bults@utwente.nl).

Ik vraag u vriendelijk of u mee wil doen aan de evaluatie van een door mij ontwikkeld regenwater opvangsystem, een innovatief system dat regenwater veel schoner opvangt dan traditionele systemen en naar behoefte schaalbaar is. U kan mij helpen door deze online-enquête in te vullen waarin u uw mening over het nieuwe systeem en de functie ervan kunt geven. Een voorbeeld vraag is: Wat vindt u goed aan dit product? Voordat u de enquête invult, wordt er een video getoond, waarin het systeem volledig wordt uitlegt. In totaal duurt deze enquête maximaal 15 minuten.

Alle informatie die u verstrekt, is anoniem en wordt niet gebruikt om (mogelijk) uw identiteit te achterhalen. De informatie wordt gebruikt voor de evaluatie voor het product en wordt geanalyseerd en in het report gezet. Zodra u de online enquête hebt voltooid, klikt u op de laatste pagina van de enquête op de knop "inleveren" en de vragenlijst wordt automatisch en volledig geanonimiseerd opgeslagen. De data wordt eind maart verwijdert.

Uw deelname is vrijwillig. U kunt op elk moment tijdens de online-enquête weigeren om verder deel te nemen en uw deelname derhalve stop te zetten. Voor onafhankelijk advies of klachten email: ethicscommittee-cis@utwente.nl .

Vink het selectievak aan indien u alles heeft begrepen wat hier boven staat. Door op 'volgende' te klikken gaat u akkoord met de bovengenoemde bepalingen.

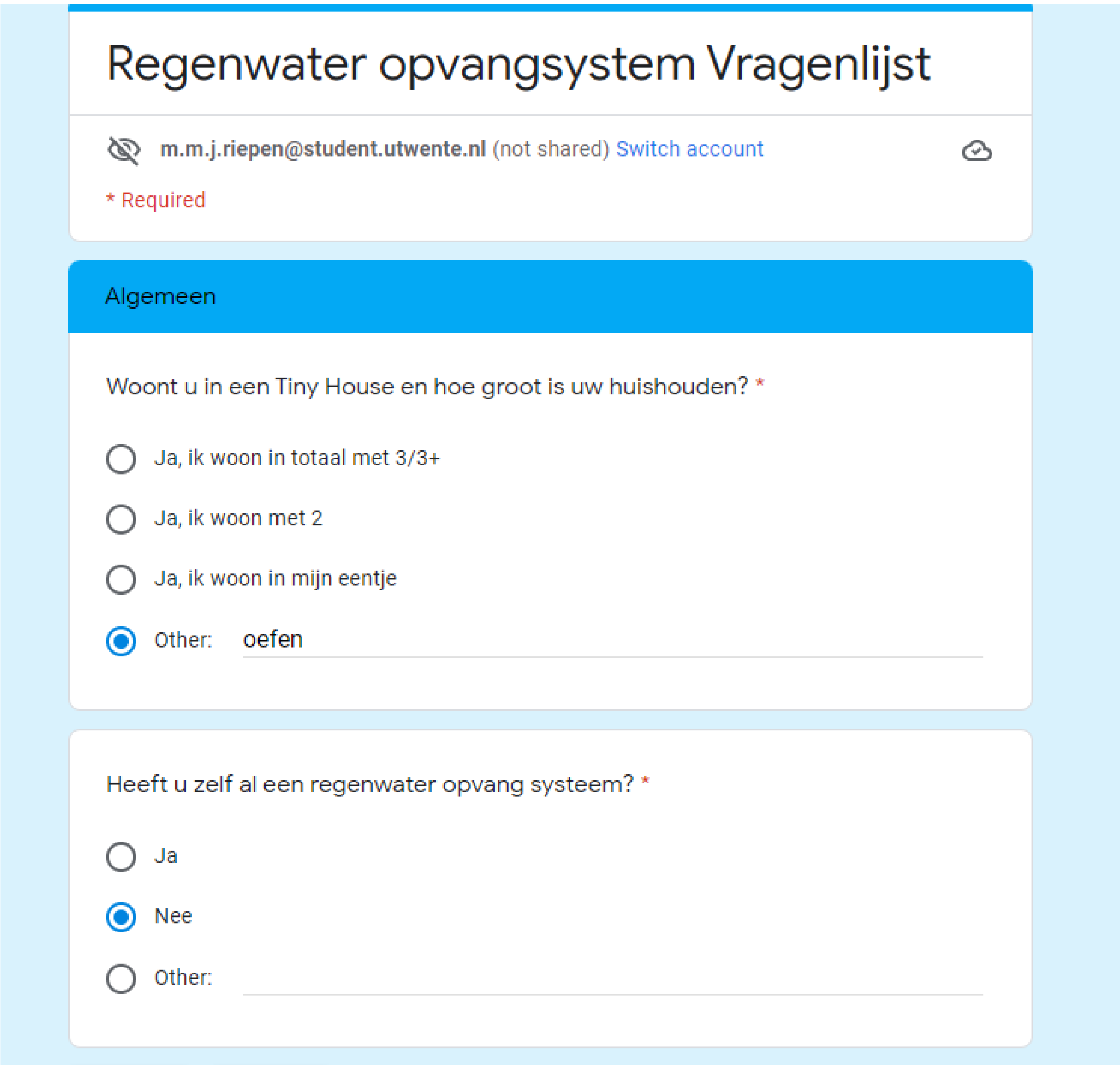
Alvast bedankt voor u medewerking!

m.m.j.riepen@student.utwente.nl (not shared) Switch account

* Required

Heeft u bovenstaande tekst begrepen en wilt u akkoord gaan en verder? *

☐ Ja ik heb alles begrepen en wil graag verder gaan.



Regenwater opvangsystem Vragenlijst

m.m.j.riepen@student.utwente.nl (not shared) Switch account

* Required

Algemeen

Woont u in een Tiny House en hoe groot is uw huishouden? *

- ( ) Ja, ik woon in totaal met 3/3+
- ( ) Ja, ik woon met 2
- ( ) Ja, ik woon in mijn eentje
- (•) Other: oefen

Heeft u zelf al een regenwater opvang systeem? *

- ( ) Ja
- (•) Nee
- ( ) Other:

Regenwater opvangsystem Vragenlijst

m.m.j.riepen@student.utwente.nl (not shared) Switch account

Video van de prototype.

In deze video wordt de prototype kortbondig uitgelegd. Hierbij ligt de focus op zijn functionaliteit. Het product komt er precies zo uit te zien.

Product uitleg met behulp van de prototype.

Wat is uw algemene indruk van dit product ?

	1	2	3	4	5	
zeer negatief	○	○	○	○	○	zeer positief

Zou u dit product willen hebben en kunt u dit toelichten?

Your answer

Wat spreekt u aan aan dit product?

- [ ] Duurzaam manier van water krijgen
- [ ] Volledig off grid kunnen wonen
- [ ] Schoon water binnen krijgen (zonder extreme filteringen)
- [ ] Volledig autonoom
- [ ] Weinig onderhoud (vergeleken met een systeem wat het dak gebruikt)
- [ ] Makkelijk te verplaatsen
- [ ] Other: ____________

Wat vindt u van de ruimte die u nodig hebt om genoeg water op te kunnen vangen voor 2 personen (60 vierkante meter)?

Your answer ____________

Hoeveel ruimte heeft u beschikbaar voor een water opvang systeem zoals dit product?

- ○ 0 - 20 vierkante meter
- ○ 20 - 40 vierkante meter
- ○ 40-60 vierkante meter
- ○ 60-80 vierkante meter
- ○ 80+ vierkante meter

Wat ziet u als het grootste nadeel van dit product?

- ○ Veiligheid voor kinderen en uzelf
- ○ Effect op de planten onder zeil
- ○ Storm veiligheid
- ○ Formaat (te groot)
- ○ Formaat (te klein, vangt te weinig water op, je moet met dit product heel zuinig zijn met water)
- ○ Ziet er niet mooi uit
- ○ Other: ____________________

Vindt u het belangrijk als het product van duurzame materialen wordt gemaakt?

	1	2	3	4	5	
helemaal oneens	○	○	○	○	○	helemaal eens

Wat mist u in het product?

- ☐ Veiligheid (Alarm, noodknop, etc)
- ☐ Moet meer water opvangen (vangt nu water op voor 2 persoons huishouden die heel zuinig met water omgaan)
- ☐ Esthetiek (zou niet mooi in de tuin staan)
- ☐ Multifunctionaliteit
- ☐ Kost energie
- ☐ Other: ____________________

Momenteel geeft een gemiddeld huishouden van 2 personen 150 euro per jaar uit aan water. Hoeveel zou u nu bereid zijn uit te geven aan dit product?

- 0 euro
- tussen 0 en 500 euro
- tussen 500 en 1500 euro
- tussen 1500 en 3000 euro
- meer dan 3000 euro

Als de prijs van water zich zou verdrievoudigen (450 euro voor 2 persoons huishouden), hoeveel zou u dan bereid zijn uit te geven aan dit product?

- 0 euro
- tussen 0 en 500 euro
- tussen 500 en 1500 euro
- tussen 1500 en 3000 euro
- meer dan 3000 euro

Als de prijs van water zich zou vertienvoudigen (1500 euro voor 2 persoons huishouden), hoeveel zou u dan bereid zijn uit te geven aan dit product?

- 0 euro
- tussen 0 en 500 euro
- tussen 500 en 1500 euro
- tussen 1500 en 3000 euro
- meer dan 3000 euro

Heeft u nog verdere ideeën om dit product te verbeteren?

Your answer

Back Submit Clear form

Data:

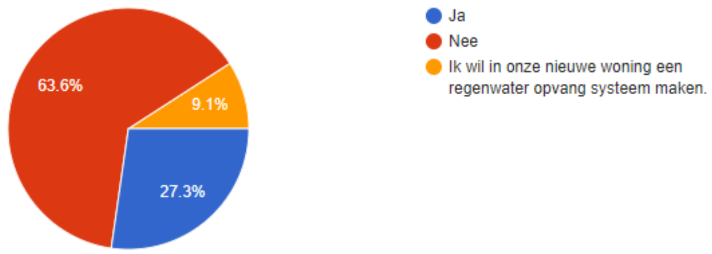
Algemeen

Woont u in een Tiny House en hoe groot is uw huishouden?

11 responses

Heeft u zelf al een regenwater opvang systeem?

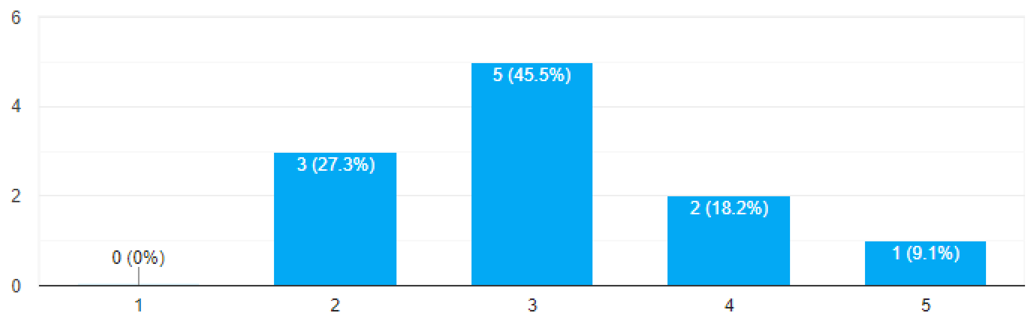
11 responses



Video van de prototype.

Wat is uw algemene indruk van dit product ?

11 responses



Zou u dit product willen hebben en kunt u dit toelichten?

11 responses

In eerste instantie wel, alleen toen zag ik dat je er nog 60m2 extra grond voor nodig hebt. Dat voelt niet praktisch.

ja, maar oppervlakte is niet realistisch bij mijn huisje

Nee, veel te duur voor drinkwatervoorziening als een on-grid mogelijkheid aanwezig is

ik zou er in ieder geval over nadenken, qua stijl past het niet echt bij mijn idee voor offgrid wonen. Het dak gaat sowieso op een aantal ingegraven vaten aangesloten worden. En er is grond water. Het idee van bewegende delen, zou voor mij naast het uiterlijk het grootste probleem zijn

Nog niet te groot voor op de grond oppervlakte

nee, het neemt te veel ruimte in beslag.

Nee, nemt veel plek in

Super praktisch systeem. Ik weet alleen niet of ik het nodig zou hebben. Ik woon namelijk on-grid en het regenwater moet dan ook nog gezuiverd worden voor ik het kan gebruiken dus voor mij is het kraanwater ideaal. Als ik offgrid zou wonen, zou ik het wel graag willen hebben om meer autonoom te zijn.

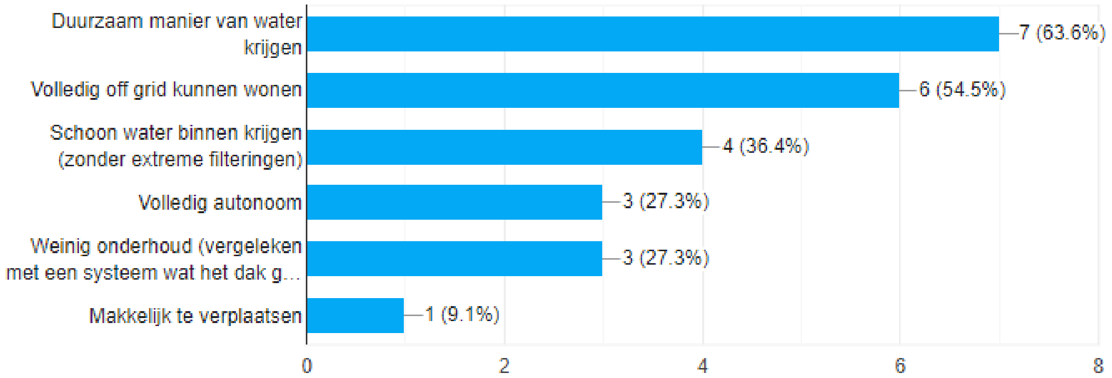
Het is extreem groot. Hoe past het in je tiny house als je op reis bent bijvoorbeeld? Wat als je geen 60m2 tot je beschikking hebt in de plek waar je woont? Hoe gaat het water naar de leidingen/tiny house aansluitingen?

Nee, omdat er op de lokatie waar ons huis komt te staan deze extra 60 m2 niet beschikbaar of toegestaan zal zijn.

In een tiny house is alle ruimte van essentieel belang. Dit product kan ten koste gaan van andere benodigdheden. Het zou een stuk ruimte efficient zijn als je het in het exterieur van de tiny house kan verwerken. Verder kan je in nederland al lastig plekken vinden om een tiny house neer te zetten. De kans dat je op je vaste en al helemaal je tijdelijke standplaats ruimte hebt voor 60m2 aan een regen opvang systeem lijkt klein.

Wat spreekt u aan aan dit product?

11 responses



Wat vindt u van de ruimte die u nodig hebt om genoeg water op te kunnen vangen voor 2 personen (60 vierkante meter)?

11 responses

Heel veel. Het kan niet op de plek waar het nu is. Daarnaast zou ik het gecombineerd willen zien met iets anders. Een andere functie, want 60m2 is veel als je tiny maar 24 is.

te veel voor bij mijn woning

Kost veel ruimte

redelijk groot en lomp in de praktijk

Te groot voor op de grond

dat is te veel

Te groot

60m2 is groot als het als 1 geheel moet worden geplaatst. Waar ik woon zou daar geen ruimte voor zijn (bosrijke omgeving en op een helling).

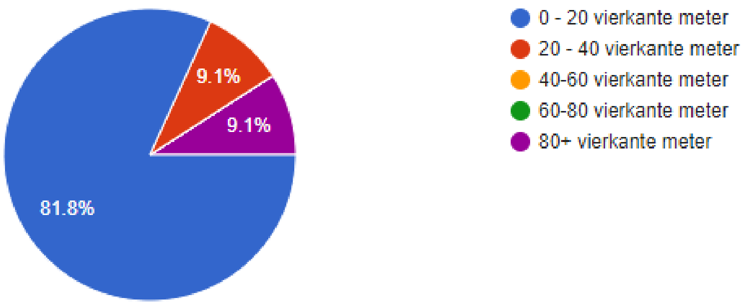
Veel

OK

Zie opmerking onder "zou u dit product willen hebben en kunt u dit toelichten"

Hoeveel ruimte heeft u beschikbaar voor een water opvang systeem zoals dit product?

11 responses

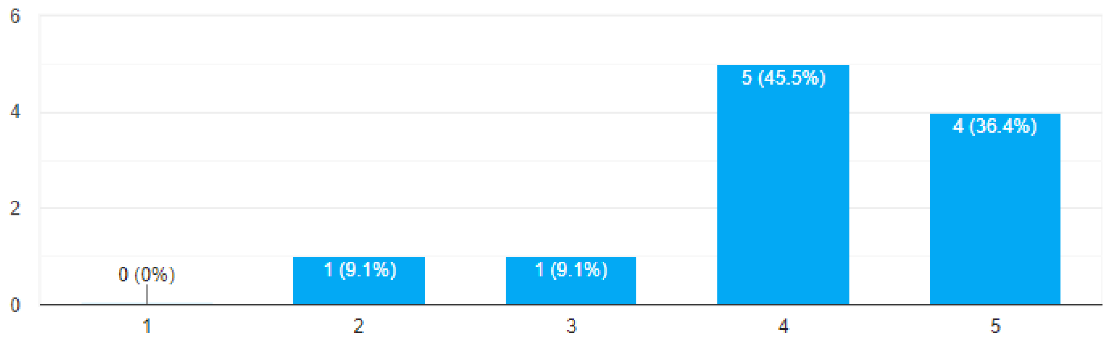


Wat ziet u als het grootste nadeel van dit product?

11 responses

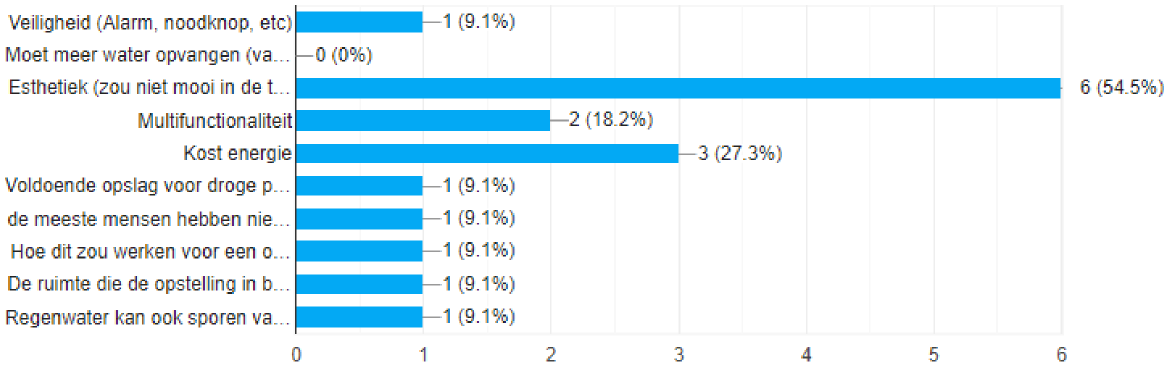
Vindt u het belangrijk als het product van duurzame materialen wordt gemaakt?

11 responses



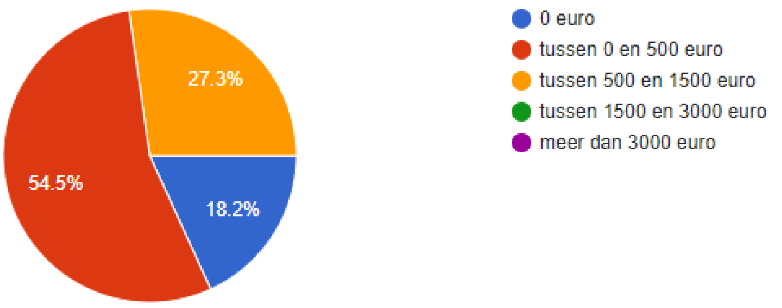
Wat mist u in het product?

11 responses



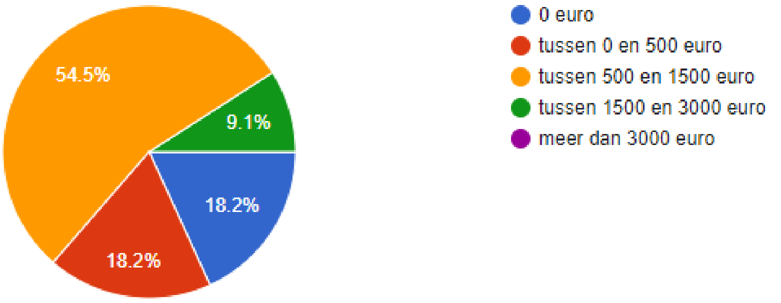
Momenteel geeft een gemiddeld huishouden van 2 personen 150 euro per jaar uit aan water. Hoeveel zou u nu bereid zijn uit te geven aan dit product?

11 responses



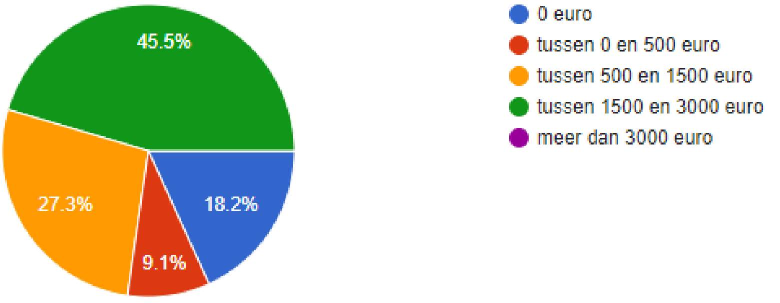
Als de prijs van water zich zou verdrievoudigen (450 euro voor 2 persoons huishouden), hoeveel zou u dan bereid zijn uit te geven aan dit product?

11 responses



Als de prijs van water zich zou vertienvoudigen (1500 euro voor 2 persoons huishouden), hoeveel zou u dan bereid zijn uit te geven aan dit product?

11 responses



Heeft u nog verdere ideeën om dit product te verbeteren?

8 responses

Waar wordt dit water opgeslagen? Laat dat ook zien. Volgens mij heb ik dan nog meer ruimte nodig.

de hoogte in; zodat deze op een dak geplaatst kan worden

Deze producten zullen nog voor een lange termijn niet kunnen concurreren met de goedkope drinkwatervoorziening in Nederland. Lijkt me dus beter om te kijken naar het buitenland waar goed drinkwater geen vanzelfsprekendheid is.

gebruik maken van de reeds gebruikte ruimte (op dak) opbouwen uit kleinere modules met minder invasief uiterlijk?

Het systeem voor het dak maken

het idee is mooi! Maar individuele toepassing bij Tiny Houses acht ik niet kansrijk. Ik zie trouwens meerdere fouten in je video, onwaarheden. Je kunt wel degelijk voldoende water opvangen op je dak, zelfs van een tiny house. Je moet wel je verbruik aanpassen aan het weer en seizoen, en voldoende opslag hebben. In mijn nieuwe Tiny House komt een regenwateropvangsysteem van JustNimbus, dat komt onder de vloer van de woning en neemt dus geen ruimte in de tuin in. Dat is echt beter denk ik. Succes!

Ik zie het opvangen van regenwater als slecht één deel van een regenwateropvangsysteem en niet persé als het belangrijkste onderdeel. Ik denk dat aan de volgende onderdelen: de opslag (container/voorraadvat/voorraadzak), de (hydrofoor)pomp om het water naar de aftappunten (toilet, plantenbak, eventueel wasmachine) te pompen, de schakeling/voorziening om automatisch over te kunnen schakelen op leidingwater als het regenwatervat leeg is.

Maak het een uitbreiding op een standaard uitrolbare caravan/4x4 auto luifel.

Appendix C: python code

```
import RPi.GPIO as GPIO
import time
import signal
import atexit
import requests
import json
from datetime import datetime
from time import sleep


class weatherApi:


    def responseHandling(self, response): #cleans raw data
        responseChunks = response.split('\r\n')
        timeArray = [r[4:10] for r in responseChunks]
        responseArray = [r[0:3] for r in responseChunks]
        del responseArray[-1]
        responseArray = map(int, responseArray)
        responseArray = list(responseArray)
        print('response', responseArray)

        print(timeArray)

        return responseArray

    def requestData(self): #request data from API Buienradar
        response =
requests.get("https://gadgets.buienradar.nl/data/raintext?lat=51.7&lon=5.30")
        newResponse = self.responseHandling(response.content.decode('utf-8'))

        print('first entry', newResponse[0])
        return newResponse

    def threshold(self, newResponse, thresholdboolean, P_button1, P_button2):
#checks if it rains now or in the coming 15 minutes.

        if newResponse[5] != 0 & thresholdboolean == False or newResponse[6] != 0
& thresholdboolean == False:
            self.servo(thresholdboolean, P_button1, P_button2)
            return True

        elif newResponse[3] != 0 & thresholdboolean == False or newResponse[4] !=
0 & thresholdboolean == False:
            self.servo(thresholdboolean, P_button1, P_button2)
            return True
         else:
            self.servo(thresholdboolean, P_button1, P_button2)
            return False

    def servo(self, thresholdboolean, P_button1, P_button2):#moves servo to the
right position
        print(thresholdboolean)
        p = GPIO.PWM(servomotor, 50)  # 50HZ
        p.start(0)

        while (thresholdboolean == True and GPIO.input(P_button1) != GPIO.HIGH):
            p.ChangeDutyCycle(7.2)  # uitrollen
```

```
            print('open')
        while (thresholdboolean == False and GPIO.input(P_button2) != GPIO.HIGH):
            p.ChangeDutyCycle(6.8)  # inrollen (close)
            print(P_button2, 'close')

        print('stop')
        p.stop()


test = weatherApi()

P_button1 = 10
P_button2 = 7
servomotor = 11
atexit.register(GPIO.cleanup)
GPIO.setmode(GPIO.BOARD)
GPIO.setup(P_button1, GPIO.IN, pull_up_down=GPIO.PUD_DOWN)
GPIO.setup(P_button2, GPIO.IN, pull_up_down=GPIO.PUD_DOWN)
GPIO.setup(servomotor, GPIO.OUT, initial=False)

while True:
    print("Lets go")
    nR = test.requestData()
    thresholdboolean = False
    thresholdboolean = test.threshold(nR, thresholdboolean, P_button1, P_button2)
    sleep(300)
```